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SYNOPSIS OF BIOLOGICAL DATA ON THE ANCHOVETA
Cetengraulis mysticetus Günther, 1866

Prepared by
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Rome, 1969

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OT Données océanographiques.

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CART Renseignements sur les pêcheries et les ressources de certains pays et régions (FD/S).

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RE Listes indexées d'experts et institutions tirées des registres tenus à jour par la Division des ressources et de l'exploitation des pêches.

CB Listes de périodiques, des sections spéciales de la « Current Bibliography for Aquatic Sciences and Fisheries », des bibliographies particulières et des articles sur les problèmes de documentation.

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Grupos especiales de sinopsis se distinguen con las siglas siguientes, seguidas por números de clasificación que se basan en las claves de los índices de la « Current Bibliography ».

SAST Datos relativos a ciertas especies y poblaciones.

MAST Sinopsis sobre métodos y materias.

OT Sinopsis sobre oceanografía.

IT Sinopsis sobre limnología.

y

CART Información sobre los recursos acuáticos vivos de algunos países y regiones (FID/S).

FAO Fisheries Technical Paper FR/T (No.)

Grupos especiales de documentos técnicos se identifican por las siglas siguientes:

RE Listas índices de expertos y de instituciones tomadas de los registros que se llevan en la Dirección de Recursos Pesqueros y Explotación.

CB Listas de periódicos, secciones especiales de la « Current Bibliography for Aquatic Sciences and Fisheries », bibliografías especiales y trabajos relativos a los problemas de documentación.

MFS Ediciones provisionales de los « Manuales de la FAO de Ciencias Pesqueras ».

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SYNOPSIS OF BIOLOGICAL DATA

ON THE ANCHOVETA

Cetengraulis mysticetus Günther, 1866

Prepared by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, October 1969

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PREPARATION OF THIS SYNOPSIS

In view of the increasing importance of anchovies in world fisheries and of the abundant data available concerning the species, this Synopsis has been prepared to disseminate the information obtained.

The details set out in this paper are based on data collected by the author in the course of personal research work on the species and also on information received from varied sources, most of which are listed in the Bibliography.

The author and the editor are particularly grateful to Mr. P. Whitehead and to Dr. A. Wheeler of the Department of Zoology, the British Museum (Natural History), for their valuable assistance in clarifying the taxonomic status of the species.

Distribution

Author
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"Current Bibliography" entry

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Eastern Pacific. Central America coast. Engraulidae. Identity. Distribution - geographic and differential. Bionomics and life history. Population. Exploitation. Management and protection.

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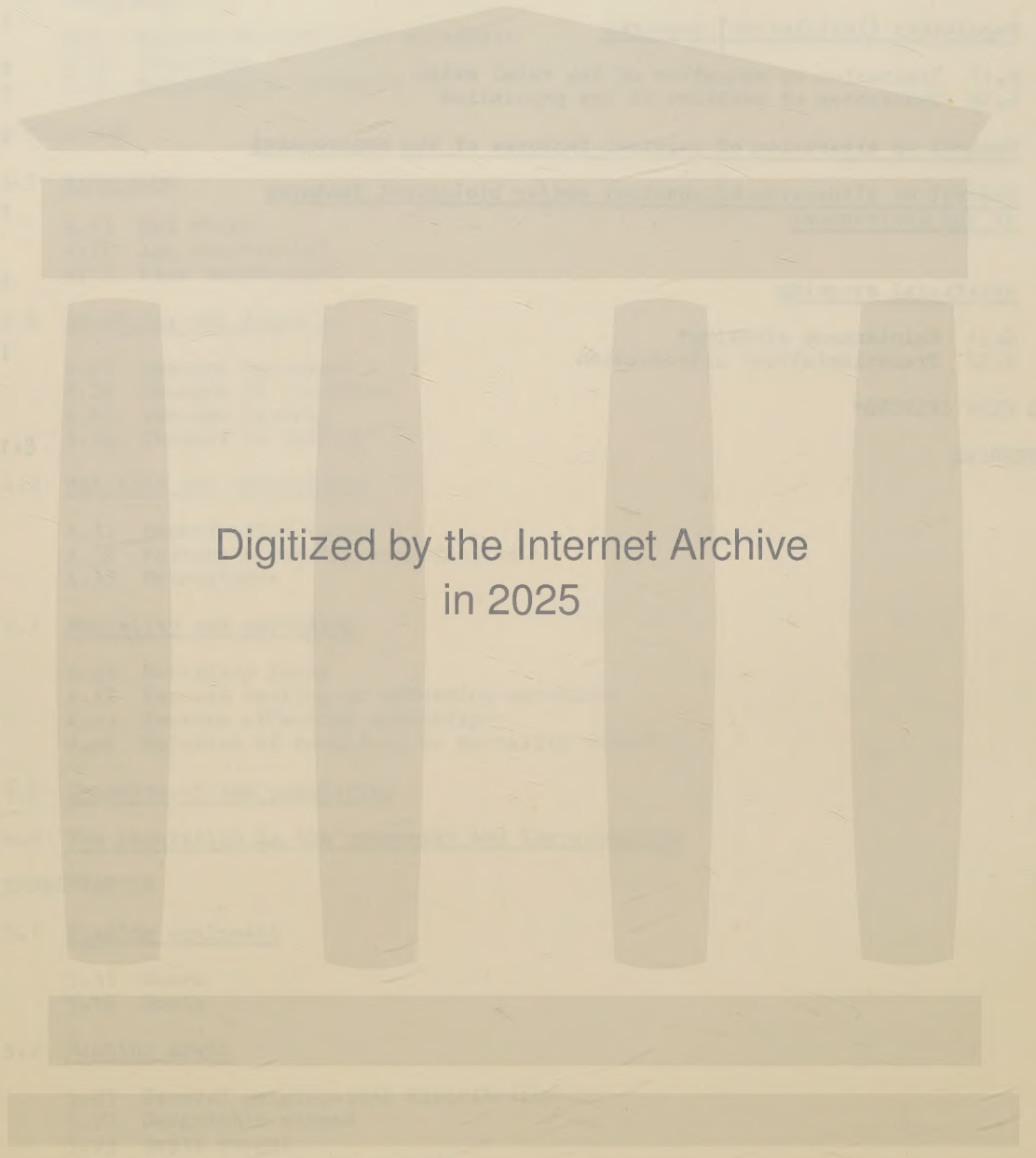
* As no information was available to the author these items have been omitted from the text.



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1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Cetengraulis mysticetus = Engraulis mysticetus Gunther, 1866.

1.12 Objective synonymy

Engraulis mysticetus Gunther, 1866: 604.

Cetengraulis mysticetus Gunther, 1868: 383; Gunther, 1869: 489: Jordan and Evermann, 1896: 450; Gilbert and Starks, 1904: 47; Meek and Hildebrand, 1923: 212; Jordan and Seale, 1926: 416; Jordan, Evermann, and Clark, 1930: 51; Seale, 1940: 4; Hildebrand, 1943: 157; Hildebrand, 1946: 104; Berdegue A., 1956: 144.

Cetengraulis muysticetus Berdegue A., 1956: 78 (lapsus calami).

Centengraulis mysticetus Anonymous, 1959:85; Anonymous, 1960a:3 (lapsus calami).

1.2 Taxonomy

1.21 Affinities

- Suprageneric

Vertebrata, Craniata, Gnathostomata, Pisces, Teleostomi, Actinopterygii, Clupeiformes, Engraulidae.

- Generic

Cetengraulis Gunther, 1868: 383; Jordan and Seale, 1925: 31; Jordan and Seale, 1926: 414; Hildebrand, 1943: 154 (genotype, Engraulis edentulus Cuvier).

This genus is distinguished by the breadth of the branchiostegal membrane and the long branchiostegal rays, the longest being about one half the length of the head. There are no gill rakers on the posterior face of the third epibranchial, and the posterior frontal fontanelles are occluded in adults (Whitehead, 1967 and personal communication).

- Specific

Holotype - British Museum (Natural History) 1864.1.26.346., standard length 124.5 mm, Pacific coast of Panama.

Paratypes (2) - British Museum (Natural History) 1863.12.16.20-1., standard lengths 111.5 and 112.0 mm, Pacific coast of Panama.

Cetengraulis mysticetus is distinguished from all other engraulids of the Pacific Ocean by the breadth of its branchiostegal membrane. It is distinguished from C. edentulus, the Atlantic species, by its larger head, lesser depth, smaller eye, and longer cheek.

Subjective synonymy

Stolephorus opercularis Jordan and Gilbert, 1882: 275; Jordan and Evermann, 1896: 445; placed in synonymy in Meek and Hildebrand (1923), reasons discussed.

Anchovia opercularis Gilbert, 1891: 449; Gilbert and Starks, 1904: 42; Kendall and Radcliffe, 1912: 81; placed in synonymy in Meek and Hildebrand (1923), reasons discussed.

Cetengraulis engymen Gilbert and Pierson, 1898: 2815; Gilbert and Starks, 1904: 48; Jordan, Evermann, and Clark, 1930: 51; placed in synonymy in Meek and Hildebrand (1923), reasons not given.

The following artificial key to the species of Cetengraulis is taken from Hildebrand (1943), but meristic and morphometric data from Howard (1954) and Berdegue A. (1958) are substituted for those given by Hildebrand for C. mysticetus.

a. Head moderately large, 3.0 to 3.4; postorbital part of head moderately long, 4.6 to 5.3; body deep, greatest depth 2.9 to 3.4 (all proportions in standard length); eye large, 3.7 to 4.6 in head; cheek equal to or shorter than snout and eye; anal fin with 23 to 26 rays, most frequently 24 or 25.

C. edentulus

aa. Head notably larger, 2.47 to 3.17; postorbital part of head very long, 3.75 to 4.0; body more slender, greatest depth 3.04 to 4.14 (all proportions in standard length); eye smaller, 4.1 to 7.4 in head; cheek notably longer than snout and eye; anal fin with 19 to 26 rays.

C. mysticetus

1.22 Taxonomic status

The taxonomic status of Cetengraulis mysticetus is clearcut, as it is the only member of its genus in the Pacific Ocean, and it is considerably different morphologically from the Atlantic Ocean species.

1.23 Subspecies

No subspecies of Cetengraulis mysticetus have been described.

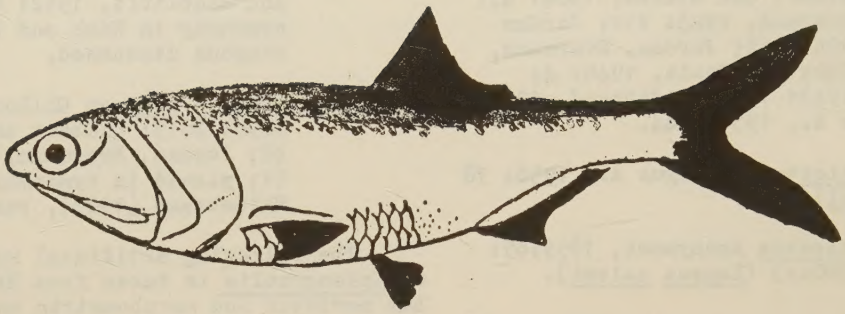


Figure 1. Cetengraulis mysticetus (Gunther). The drawing was made from a specimen 144 mm in standard length, U.S. National Museum, Catalogue No. 79609 (Hildebrand, 1943).

1.24 Standard common name and vernacular names

In scientific literature "anchoveta" is invariably used as the common name for Cetengraulis mysticetus. The following vernacular names are used by fishermen:

U.S.A. (i.e. U.S. fishermen who catch it off the coasts of the Latin American countries): anchoveta

Mexico

northern: sardina, anchoveta, bocona
southern: sardina

Costa Rica: anchoveta

Panama: sardina, cardume, anchoveta

Colombia: cardume, anchoveta

Ecuador

Esmeraldas: ojito, chuhueco, anchoveta
Manta and Gulf of Guayaquil: ojito, anchoveta.

1.3 Morphology

1.31 External (Fig.1) and internal morphology

Howard (1954), Harder (1958), and Berdegue A. (1958) have made studies of the meristic and morphometric characters of the anchoveta from 12 of its most important areas of occurrence. Their data are summarized in Table I. The vertebral counts include the atlas and urostyle. The anal fin ray counts include the first ray, visible only by dissection. The gill raker counts include only the gill rakers on the lower portion of the first gill arch. The number of gill rakers increases with the length of the fish, but the relationship is not linear, and cannot be made so by any simple transformation. Therefore only the gill raker counts of Berdegue A. (1958), who studied only fish from 100 to 130 mm in standard length, are included in the table. The scale counts include the number of scales in a longitudinal series from the upper angle of the operole to the end of the caudal peduncle. The measurements of the alimentary tract extend from the anterior end of the mouth to the anus. Measurements of fish of 100 to 130 mm were employed for the calculation of the regressions of the head length on standard length, body depth on standard length, and eye diameter on head length.

Significant differences for at least one meristic or morphometric character were found for each of the pairs of areas for which comparisons were made (Table II). These differences indicate that the population of anchovetas in the eastern Pacific Ocean is not a homogeneous mixture, but it is not possible to determine from meristic or morphometric studies whether the segregation of fish by areas is complete. The fish of all the areas could originate from one or a few subpopulations of spawners, and the differences between fish of different areas could be caused by the environment. From what is known of the life history (Section 3), however, it appears far more likely that the fish of the different areas belong to distinct subpopulations.

Hildebrand (1943) states that the anchoveta "acquires an excessively large head with age." Howard (1954) demonstrated that the gill raker counts increase with increasing size. Bayliff (1963a) examined the structures associated with feeding and digestion and found that: "the gill rakers are about the same length relative to the length of the gill arch in all sizes of fish...; the gill rakers are more closely spaced on the gill arch in the smaller fish...; the processes on the gill rakers are longer in relation to the rakers on the smaller fish...; the processes are more closely spaced on the gill rakers in the smaller fish...; the length of the intestine increases at a much greater rate than the standard length in juvenile fish."

TABLE I

Meristic and morphometric data for the anchoveta, obtained from Howard (1954), Harder (1958), and Berdegue A. (1958)

	Number of fish with vertebral counts of					Number of fish with dorsal fin ray counts of					Number of fish with anal fin ray counts of							
	39	40	41	42	43	13	14	15	16	17	19	20	21	22	23	24	25	26
Almejas Bay	-	13	246	89	2	1	19	82	23	-	-	-	9	50	94	65	6	2
San Felipe Bay	-	7	38	2	-	-	-	-	-	-	-	-	1	13	8	6	-	-
Guaymas Bay	1	24	274	38	-	1	8	102	14	-	1	2	18	92	86	24	2	-
Ahome Point	2	22	280	46	-	-	9	91	25	-	-	3	23	74	96	26	3	-
Banderas Bay	1	7	76	16	-	-	-	-	-	-	-	-	7	27	49	17	-	-
Gulf of Tehuantepec	-	1	28	3	-	-	-	-	-	-	-	-	1	10	9	7	2	-
Gulf of Fonseca	1	9	205	35	-	-	16	94	15	-	-	2	9	40	57	17	-	-
Gulf of Nicoya	-	4	60	11	-	-	-	-	-	-	-	-	8	21	34	12	-	-
Montijo Bay	-	2	36	8	-	-	-	-	-	-	-	-	-	12	10	6	3	-
Gulf of Panama	-	16	296	38	-	-	16	84	25	-	-	1	5	41	113	58	7	-
Colombia	1	9	82	7	-	-	-	-	-	-	-	-	1	27	39	17	4	-
Gulf of Guayaquil	-	16	206	28	-	-	11	93	20	1	-	-	4	31	52	29	9	-

TABLE I (continued)

	Number of fish with gill raker counts of																	Number of fish with scale counts of												
	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	30	31	32	33	34	35	36	37	38	39	40	41	42
Almejas Bay	-	-	2	3	3	5	9	12	19	17	8	12	6	1	2	1	-	-	-	-	-	6	11	18	18	21	16	6	3	1
San Felipe Bay	-	-	-	3	5	4	6	5	1	3	1	-	-	-	-	-	-	1	3	4	5	2	3	7	1	1	1	-	-	-
Guaymas Bay	-	-	1	1	1	8	11	9	15	21	13	6	9	3	2	-	-	-	-	-	4	9	12	12	16	15	12	10	8	2
Ahome Point	-	-	-	-	2	-	6	8	15	13	16	17	10	8	4	1	-	-	-	-	-	-	6	9	22	20	17	16	7	3
Banderas Bay	-	-	-	1	1	1	5	9	18	18	20	11	8	6	-	1	1	-	-	-	-	1	12	16	17	19	18	12	5	-
Gulf of Tehuantepec	-	-	-	-	1	-	1	4	3	9	6	3	1	3	-	-	-	-	-	-	-	-	-	3	4	9	10	4	1	-
Gulf of Nicoya	-	-	2	4	19	11	11	12	7	7	1	1	-	-	-	-	-	-	-	-	-	5	11	11	13	13	12	9	1	-
Montijo Bay	1	2	3	2	4	4	7	5	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6	9	7	4	2	-
Gulf of Panama	1	2	2	4	2	6	11	13	11	17	11	10	5	4	1	-	-	-	-	-	1	3	8	14	16	25	19	10	2	2
Colombia	-	-	-	-	3	1	9	11	17	20	15	6	4	1	1	-	-	-	-	1	5	4	8	15	16	15	15	7	1	1

TABLE I (continued)

	Regression of alimentary tract length (Y) on standard length (X)	Regression of head length (Y) on standard length (X)	Regression of body depth (Y) on standard length (X)	Regression of eye diameter (Y) on head length (X)
Almejas Bay	Y = -408.136 + 10.422X	Y = 9.9256 + 0.28338X	Y = -1.8596 + 0.28748X	Y = 4.2459 + 0.08705X
San Felipe Bay		Y = -1.9244 + 0.37376X	Y = -2.4607 + 0.28961X	Y = 2.0464 + 0.15773X
Guaymas Bay		Y = 6.2103 + 0.31459X	Y = 1.1089 + 0.25523X	Y = -2.7323 + 0.24241X
Ahome Point		Y = 1.7872 + 0.34415X	Y = -13.2097 + 0.38225X	Y = 0.6313 + 0.14727X
Banderas Bay		Y = 4.8763 + 0.32507X	Y = -5.8704 + 0.32228X	Y = 1.4446 + 0.10405X
Gulf of Tehuantepec		Y = -3.0254 + 0.39058X	Y = -3.1884 + 0.31613X	Y = 0.9461 + 0.14883X
Gulf of Fonseca	Y = -513.946 + 11.657X			
Gulf of Nicoya		Y = 9.9550 + 0.26513X	Y = -17.4980 + 0.43576X	Y = 2.1258 + 0.14393X
Montijo Bay		Y = 6.6139 + 0.30267X	Y = 7.4162 + 0.36722X	Y = 2.2580 + 0.14710X
Gulf of Panama	Y = -944.739 + 16.294X	Y = -7.4508 + 0.43353X	Y = 5.6373 + 0.33516X	Y = 2.9568 + 0.11847X
Colombia		Y = 0.9662 + 0.37142X	Y = 3.8806 + 0.23624X	Y = 8.4976 + 0.00125X

TABLE II

Summary of differences in the meristic and morphometric characters of anchovetas of different areas. The statistically significant differences are indicated by: V, vertebral counts; A, anal fin ray counts; G, gill raker counts; S, scale counts; I, ratios of length of alimentary tract to standard length; H, ratios of head length to standard length; D, ratios of body depth to standard length; E, ratios of eye diameter to head length. The dashes indicate that no comparisons were made for the pairs of areas. The data are from Howard (1954), Harder (1958), and Berdegue A. (1958)

	Almejas Bay	San Felipe Bay	Guaymas Bay	Ahome Point	Banderas Bay	Gulf of Tehuantepec	Gulf of Fonseca	Gulf of Nicoya	Montijo Bay	Gulf of Panama	Colombia
San Felipe Bay	VGSHE										
Guaymas Bay	VADE	GSHE									
Ahome Point	VAGSHE	GSE	GSHDE								
Banderas Bay	VGE	GSHE	DE	H							
Gulf of Tehuantepec	VSDE	GSHDE	SDE	HDE	GDE						
Gulf of Fonseca	VAGI	-	G	G	-	-					
Gulf of Nicoya	VGHDE	SHDE	GHDE	GSHDE	GHDE	GHE	-				
Montijo Bay	VGSHDE	VSD	GSHDE	GDE	GHDE	GHDE	-	SHD			
Gulf of Panama	VIHD	VAGSHDE	AHDE	AGHDE	AGHDE	GE	AGI	AGHDE	GHDE		
Colombia	VH	GSHE	HE	AGSHE	GHDE	SHDE	-	GHDE	GSHDE	HD	
Gulf of Guayaquil	VG	-	AG	AG	-	-	AG	-	-	G	-

2 DISTRIBUTION

2.1 Total area

The areas where the anchoveta has been recorded are shown in Fig. 2 and listed in Table III. It is obviously a tropical and subtropical species. Adult anchovetas nearly always occur over shallow mud flats, and thus the distribution is not continuous. Most of the areas where it is found are near the mouths of rivers.

Data on the sea-surface temperatures at or near the areas where anchovetas occur are given by Anon., (1962). The lowest and highest mean monthly temperatures for areas where anchovetas occur regularly in commercial quantities are 17.5°C for Guaymas Bay in January and 30.8°C for La Union, El Salvador (Gulf of Fonseca) in August. Peterson (1956) states that prior to their virtual disappearance from the Gulf of Nicoya anchovetas were caught there in commercial quantities as far inland as Chira Island. Peterson (1960) records salinities at that location at the surface and at 5 and 10 m as low as 20 parts per thousand. In most of the areas where the anchoveta occurs, however, the salinity is greater than 30 parts per thousand.

2.2 Differential distribution

2.21 Spawn, larvae, and juveniles

In the Gulf of Panama spawning of the anchoveta occurs over shallow mud flats, and the eggs and larvae are found there (Simpson, 1959). The juveniles are found at the surface, often near rocky islands, in water to about 60 m deep.

2.22 Adults

The adults occur over shallow mud flats. The seasonal variation in the Gulf of Panama associated with spawning is discussed in Section 3.16.

2.3 Determinants of distribution changes

In 1947 the anchoveta population in the Gulf of Nicoya suffered a severe decline, and since then the abundance has been low there. Peterson (1956) states that the decline could have been the result of a reported heavy bloom of red tide, presumably Gymnodinium sp., which occurred there at about the same time.

2.4 Hybridization

Hybridization of the anchoveta with other species has not been reported.

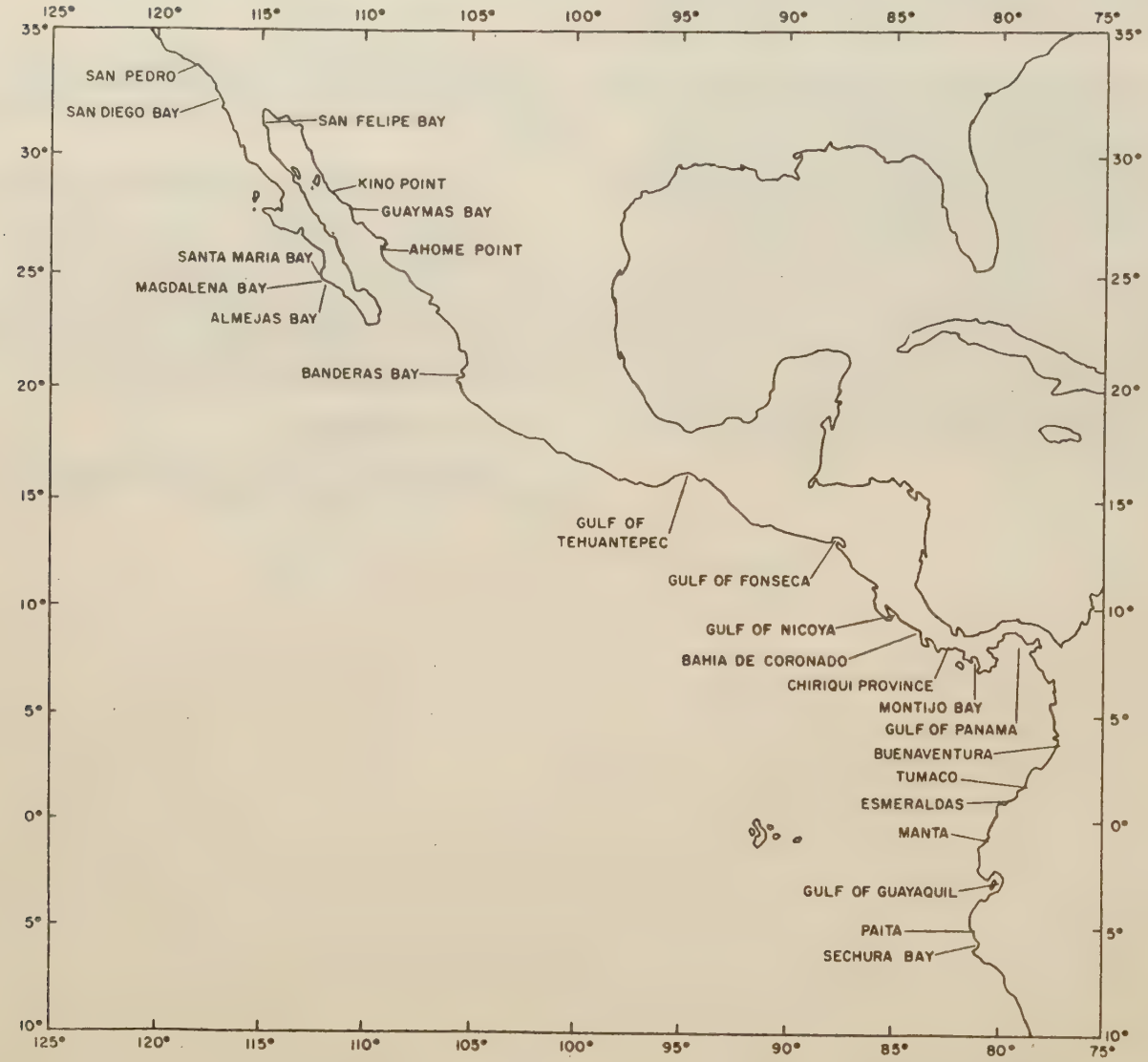


Figure 2. Areas where the anchoveta has been recorded.

TABLE III

Areas where the anchoveta has been recorded.
The designations of the regions follow the system of Rosa (1965)

Region	Area	Geographical coordinates	Reference
4.6.3 California waters	San Pedro, U.S.A.	33°40'N-118°15'W	McHugh and Fitch, 1951
	San Diego Bay, U.S.A.	32°40'N-117°15'W	Ibid.
	Santa Maria Bay, Mexico	24°45'N-112°15'W	Alverson and Shimada, 1957
	Magdalena Bay, Mexico	24°40'N-112°00'W	Barrett and Howard, 1961
	Almejas Bay, Mexico	24°30'N-111°40'W	Ibid.
4.6.4 West Mexican waters	San Felipe Bay, Mexico	31°00'N-114°50'W	Berdegue A., 1958
	Kino Point, Mexico	28°45'N-112°00'W	Alverson and Shimada, 1957
	Guaymas Bay, Mexico	27°50'N-110°50'W	Howard, 1954
	Ahome Point, Mexico	25°55'N-109°30'W	Ibid.
	Banderas Bay, Mexico	20°40'N-105°30'W	Berdegue A., 1958
	Gulf of Tehuantepec, Mexico	16°00'N- 94°45'W	Ibid.
	Gulf of Fonseca, El Salvador, Honduras, and Nicaragua	13°05'N- 87°40'W	Howard, 1954
	Gulf of Nicoya, Costa Rica	10°00'N- 85°00'W	Peterson, 1956
	Bahia de Coronado, Costa Rica	8°50'N- 83°45'W	Bayliff, 1963b
	Chiriqui Province, Panama	8°00'N- 83°00'W	Ibid.
	Montijo Bay, Panama	7°45'N- 81°10'W	Berdegue, A., 1958

TABLE III (continued)

Region	Area	Geographical coordinates	Reference
4.8 Pacific Equatorial Countercurrent region	Gulf of Panama, Panama	8°50'N- 79°20'W	Howard, 1954
	Buenaventura, Colombia	3°45'N- 77°15'W	Barrett and Howard, 1961
	Tumaco, Colombia	1°55'N- 78°40'W	Ibid.
	Esmeraldas, Ecuador	1°00'N- 79°40'W	Ansaldo Garces, 1964
4.9.4 Peru-Galapagos waters	Manta, Ecuador	0°50'S- 80°40'W	Barrett and Howard, 1961
	Gulf of Guayaquil, Ecuador	3°00'S- 80°00'W	Howard, 1954
	Paita, Peru	5°05'S- 81°10'W	Barrett and Howard, 1961
	Sechura Bay, Peru	5°40'S- 80°55'W	Hildebrand, 1943

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

The sexes of the anchoveta are separate. The males and females cannot be distinguished by external characters. Howard (1954) found no significant differences in the counts of the vertebrae, dorsal or anal fin rays, or gill rakers of male and female anchovetas from the same area. Berdegue A. (1958) encountered the same results for the ratios of the head length to standard length, body depth to standard length, and eye diameter to head length.

3.12 Maturity

As far as is known, the anchoveta invariably reaches sexual maturity at 1 year of age (Howard and Landa, 1958; Barrett and Howard, 1961; Bayliff, 1963b; Ansaldo Garces, 1964). Howard and Landa (1958) and Barrett and Howard (1961) give the following data on the mean standard length at first maturity: Almejas Bay, 127 mm; Guaymas Bay, 128 mm; Ahome Point, 132 mm; Banderas Bay, 115 mm; Gulf of Fonseca, 128 mm; Gulf of Panama, 126 mm; Colombia, 126 mm; Gulf of Guayaquil, 118 mm. Bayliff (1966) gives the average weight of 1-year-old fish in the Gulf of Panama as 31.71 g.

3.13 Mating

The mating of the anchoveta has not been observed, but it is probably promiscuous.

3.14 Fertilization

The fertilization of the eggs of the anchoveta takes place externally.

3.15 Gonads

Peterson (1961) calculated the following fecundity relationships for mature anchovetas from the Gulf of Panama:

$Y = -101{,}200 + 1{,}006X$ (standard error of estimate = 9,147) where Y = number of mature ova and X = standard length of fish in millimeters, and

$Y = -3{,}304 + 927X$ (standard error of estimate = 9,313) where Y = number of mature ova and X = weight of fish in grams.

Howard and Landa (1958) calculated gonad indices by

$$\text{gonad index} = \frac{\text{width of gonad in mm} \times 100}{\text{standard length of fish in mm}}$$

Barrett and Howard (1961) classified the fish by this gonad index as follows: <3, "maturing;" 3-6, "approaching the advanced sexual stage;" >6, "most advanced sexually".

Howard and Landa (1958) have shown that the anchoveta produces only one batch of eggs each spawning season in the Gulf of Panama, and Barrett and Howard (1961) reached the same conclusion for the fish of the Gulf of Fonseca. The maximum age recorded for the anchoveta is about 38 or 39 months (Section 3.31), so a fish attaining this age would spawn three times during its lifetime. From Bayliff's (1966) weight data and Peterson's (1961) weight-fecundity relationship it is estimated that a female anchoveta in the Gulf of Panama would produce about 26,000, 48,000, and 60,000 eggs at 1, 2, and 3 years of age, respectively.

3.16 Spawning

The spawning periods of the anchoveta in various areas are shown in Table IV. The spawning period is prolonged in most areas, and relatively few collections of fish are available from most of these, so it is difficult to determine if there is one or more than one peak of spawning activity during the spawning period. Barrett and Howard (1961) found evidence that in Almejas Bay there are two peaks of spawning activity, one in August-September and one in December-January. For the Gulf of Panama, however, where the most detailed studies have been made (Howard and Landa, 1958; Simpson, 1959; Klima, Barrett, and Kinnear, 1962), there appears to be only a single peak of spawning activity. There is no evidence of more than one peak of spawning activity in any of the other areas (Barrett and Howard, 1961; Bayliff, 1963b; Ansaldo Carces, 1964).

Spawning occurs from 01.30 to 04.30 in the Gulf of Panama (Simpson, 1959; Klima, Barrett, and Kinnear, 1962).

Simpson (1959) hypothesized that the ultimate cause of spawning in November and December in the Gulf of Panama is the fact that upwelling occurs there from December to March, which increases the supply of plankton for food for the larvae, postlarvae, and juveniles. Variation in the time of the spawning period in different years in that area has been discussed by Simpson (1959) and by Bayliff (1964). Simpson discussed temperature, salinity, and light as possible proximate causes of this variation, but his findings were inconclusive.

Spawning occurs over shallow mud flats. Simpson (1959) has shown that in the Gulf of Panama in the 1956-1957 and 1957-1958 spawning seasons spawning occurred chiefly from the entrance of the Panama Canal to Punta de Brujas (Fig. 3), though anchovetas reside beyond this area during most of the year. It is not known if this is the principal spawning area in other years also, or why it was preferred in those years.

The sex ratio on the spawning grounds is discussed in Section 4.11.

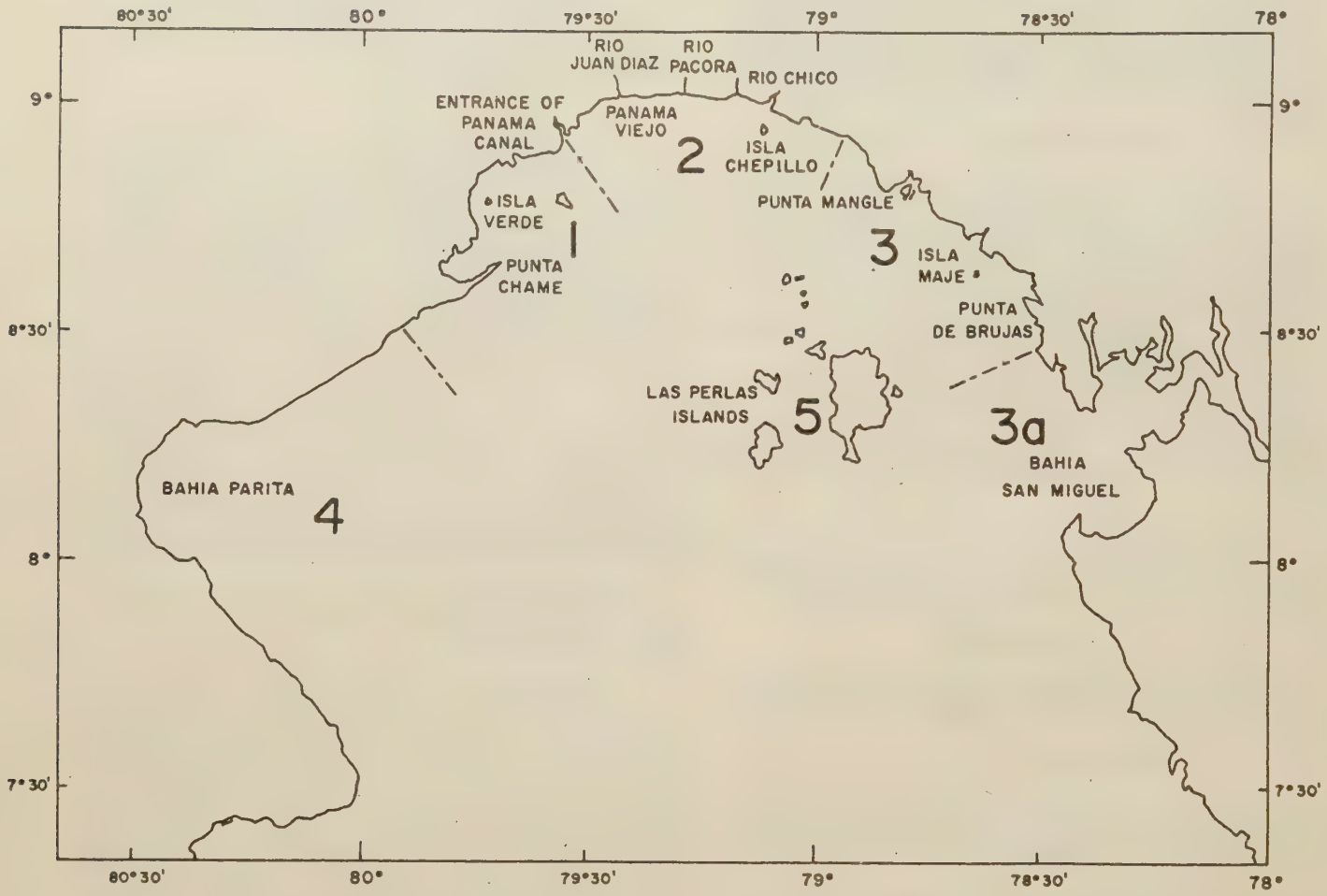


Figure 3. Map of the Gulf of Panama, showing the areas mentioned in the text.

TABLE IV

Spawning periods of the anchoveta in different areas

Area	Spawning period	Reference
Almejas Bay	August–February, with possible peaks in August–September and December–January	Barrett and Howard, 1961
Guaymas Bay	July–December, with peak in September–October	Ibid.
Ahome Point	June–September, and possibly to December	Ibid.
Banderas Bay	Sometime from June to December; probably closer to December	Ibid.
Gulf of Fonseca	September–December, with some activity taking place prior to September	Ibid.
Chiriqui Province	Chiefly in November and December	Bayliff, 1963b
Montijo Bay	Throughout the year, with peak in November–December	Ibid.
Gulf of Panama	October–January, with peak in November–December	Howard and Landa, 1958; Simpson, 1959; Klima, Barrett, and Kinnear, 1962
Colombia	October–February	Barrett and Howard, 1961
Esmeraldas	March–August	Ansaldo Garces, 1964
Gulf of Guayaquil	March–September	Ibid.
Gulf of Guayaquil	December–March, with peak in December–January	Barrett and Howard, 1961

3.17 Spawn

The egg of the anchoveta is pelagic and non-adhesive. It is oval, the mean dimensions of its major and minor axes being 1.166 (range 0.986 to 1.360) and 0.558 (range 0.493 to 0.663) mm, respectively (Simpson, 1959). Forsbergh (1969) estimated its weight to be 0.193 mg. It is unpigmented and translucent, it has no oil globule, and the yolk is segmented. The egg membrane is unsculptured (Simpson, 1959).

3.2 Pre-adult phase

3.21 Embryonic phase

Simpson (1959) distinguished the planktonic egg of the anchoveta from those of 19 other species of anchovies in the Gulf of Panama by its dimensions and by its abundance relative to other anchovy eggs during the spawning season of the anchoveta and at other times. His identification was corroborated by Klima, Barrett, and Kinnear (1962), who mixed the eggs and milt from sexually mature anchovetas and obtained fertile eggs identical to those described by Simpson.

The timetable for the development of an egg fertilized at 03.00, as interpreted from Simpson (1959), is approximately as follows:

- 04.00 – 16-cell stage;
- 06.30 – blastopore lip begins to become defined;
- 09.00 – overgrowth of yolk mass by embryonic tissue 1/2 completed;
- 11.30 – blastopore closes, 3 to 5 myotomes apparent at center of embryo;
- 12.00 – tail becoming prominent, optic cup developing;
- 13.00 – tail extends to posterior margin of yolk, 12 to 17 myotomes;
- 14.00 – tail not yet lifted away from yolk, 16 to 21 myotomes, eyes plainly visible, heart begins to beat;
- 15.00 – extremity of tail lifted away from yolk, 22 to 25 myotomes;
- 16.00 – 26 to 29 myotomes;
- 17.00 – tail extends anteriorally about 1/8 the embryo's length, 30 to 34 myotomes, development of dorsal and ventral fin folds begins;
- 18.00 – tail extends anteriorally about 1/3 the embryo's length, 34 to 38 myotomes, cross striations begin to develop in myotomes at centre of embryo;
- 19.00 – tail extends anteriorally about 2/5 the embryo's length, adult number of myotomes (39 to 42);
- 20.00 – auditory capsule clearly defined;
- 22.30 – hatching.

In the early stages the eggs floated at the surface of containers in the laboratory, but near the time of hatching they sank to the bottom. Hatching is effected by rupture of the egg case due to movements of the embryo's tail. Immediately after breaking the egg case the embryo lies motionless for a short time before freeing itself from the egg case.

3.22 Larval phase

The following description of the development of the anchoveta larvae obtained from eggs hatched and reared in the laboratory is taken from Simpson (1959):

- hatching – no mouth, eyes unpigmented, chorionic fissure, nerve cord, and notochord plainly visible, pectoral fin buds forming, total length 2.0 mm;
- 12 hr after hatching – yolk sac 1/2 absorbed, cranial flexure almost disappeared, no pigmentation yet developed, jaw rudiments developing, actinotrichia developing in caudal fin region, total length 2.7 mm;
- 18 hr after hatching – yolk sac 2/3 absorbed, jaws further developed, pectoral fin buds and otic cup well developed;
- 24 hr after hatching – yolk sac 4/5 absorbed, pigmentation appears on eyes and, in a few specimens, along ventrolateral margins of intestine, total length 2.8 mm (after which no further growth in length was evident in the larvae reared by Simpson);
- 36 hr after hatching – yolk sac 9/10 absorbed, pigmentation on eyes, ventrolateral margin of intestine, and caudal myotomes, pectoral fin consists of a fleshy base with a wide membrane which does not yet contain fin rays;
- 39 hr after hatching – yolk sac completely absorbed;
- 48 hr after hatching – functional mouth developed, intestine wider, pigmentation further developed, ossification of cleithrum begins.

The larvae reared in the laboratory all died within 154 hr after hatching, probably due to lack of suitable food (Klima, Barrett, and Kinnear, 1962). Their development was probably abnormal after absorption of the yolk sac, so descriptions were not prepared from these larvae. Characters for distinguishing anchoveta larvae collected in plankton from the larvae of other species of anchovies have not been found, so descriptions of the larvae cannot be prepared from these either.

3.23 Adolescent phase

When it reaches about 25 mm in standard length the anchoveta is first distinguishable from other anchovies by the membrane connecting the gill covers to the isthmus and by the coiled intestine (Klima, Barrett, and Kinnear, 1962). At this time it resembles the adult except for the gill raker counts, which increase with increasing length, and the length of the intestine relative to the standard length, which increases until the fish reach about 110 mm (Section 1.31).

Anchovetas of 20 to 30 mm were sampled by Simpson (1959) with a fine-meshed otter trawl dragged on the bottom between the mouths of Rio Chico and Rio Juan Diaz, Gulf of Panama, at depths of about 2 to 4 m. Bayliff (1964) recorded the capture of anchovetas of 22 to 59 mm in Balboa Harbor, at the mouth of the Panama Canal, at a depth of about 4 m. The fish apparently move offshore at lengths between about 20 and 60 mm and remain there for about 1 to 3 months. Simpson (1959) and Bayliff (1964) record their presence in deeper (to about 60 m), clearer water, particularly near islands, in the Gulf of Panama. At this time they are preyed upon by laughing gulls, Larus atricilla, and larger fish (Simpson, 1959), including Lutjanus sp. (Kendall and Radcliffe, 1912).

In March, April, and May, when the fish in the Gulf of Panama reach about 90 to 120 mm, they migrate inshore to shallow mud flats, where they spend the rest of their lives. These fish are about 4 to 5 months old, and are considered to become adults at this time, as their mode of life is henceforth the same as that of the fish 1 or 2 years older.

3.3 Adult phase

3.31 Longevity

It is clear from age composition data (Section 4.12) that the average life expectancy of the anchoveta is less than 1 year. The maximum age recorded for this species in the Gulf of Panama is about 38 or 39 months, this being determined from length-frequency and tag return data (Bayliff, 1964, 1966, 1967). The maximum age recorded in other areas is 28 months for fish from Ecuador-Peru (Bayliff, 1967). It is believed that older fish exist in these areas, but the ages were determined only from length-frequency data, and because of inadequate samples and overlapping of the lengths not more than two age groups could be distinguished.

3.32 Hardiness

The anchoveta is esteemed as a bait fish for tunas because of its ability to live in captivity aboard fishing vessels (Godsil, 1938; Alverson and Shimada, 1957). No data concerning its hardiness when carried aboard these vessels are available, however. Bayliff and Klima (1962) have presented some data on the survival of anchovetas in live boxes. These fish were captured with cast nets and transported about 15 km in the live well of a log canoe to live boxes anchored in a sheltered harbor in the Gulf of Panama, where they were retained. The mortalities of the fish in their first year of life during the first few days (2 to 8) after capture were highly variable, ranging from 3 to 68%, but in most cases were less than 35%. After the first few days few fish died. In one case 300 fish in their second year of life were placed in a live box, and all but 6 of these died the first 3 days after capture. Larger fish are avoided by tuna fishermen, as they are known to survive poorly in captivity. On May 18 and 19, 1959, two experiments were initiated with 400 fish captured about 1 week previously, and on December 22, 7 months later, 34 of these still survived. They were fed finely-ground corn meal, as is sometimes done on tuna boats, and at times appeared to attempt to ingest this, but when the experiments ended they were highly emaciated. On May 27, 28, and 29, 1960, 660 newly-captured fish were placed into the live boxes, and on September 1, 3 months later, 63 still survived. These were not fed at all, but they appeared to be no more emaciated than those of the previous year.

3.33 Competitors

No specific information is available on the competitors of the anchoveta. It feeds chiefly on diatoms and detritus on the bottom (Section 3.4), so it is likely that its competitors for food are chiefly invertebrates.

3.34 Predators

The most conspicuous predator of the anchoveta is the pelican, Pelecanus occidentalis carolinensis. These can be seen frequently in large numbers diving for anchovetas. The frigate bird, Fregata magnificens, has also been observed to prey on the anchoveta. It is consumed by various larger fishes, including Cynoscion othonopterus (Jordan and Gilbert, 1882) and C. macdonaldi (Berdegue A., 1956). Flight is probably its only defense mechanism.

3.35 Parasites, diseases, injuries, and abnormalities

There are no data on parasites or diseases of the anchoveta.

Anchovetas are frequently observed with reddened areas at the tip of the snout and on the lower jaw. This may be the result of feeding by stirring up the mud on the bottom. Partially-healed wounds and scars, presumably inflicted by predators, are seen frequently on anchovetas. The live-box experiments of Bayliff and Klima (1962) demonstrated the rapid healing ability of the anchoveta. External tags of various types were applied to the dorsal musculature near the dorsal fin, to the dorsal and ventral musculature

posterior to the anus, and to the operole. The tags were shed rapidly, and in about 2 weeks the wounds were completely healed, without scars. Such foreign substances as latex, inorganic chemicals, and insoluble fluorescin dyes were also shed rapidly, and the point of injection healed completely in less than 1 week. Internal tags were inserted into the body cavity through a slit near the anus. In most cases the slit healed in about 1 week, but sometimes it became infected and enlarged, in which case it took longer to heal.

In the course of tagging about 50,000 anchovetas with internal tags the writer observed about 20 individuals with both ventral fins missing. It appeared that the entire pelvic girdle was absent, but none of the fish was dissected or x-rayed to confirm this.

3.4 Nutrition and growth

3.41 Feeding

The feeding of the anchoveta in the Gulf of Panama has been investigated by Bayliff (1963a). The juveniles are plankton feeders. From the fineness of the gill rakers (Section 1.31) and the minute sizes of the foods found in the stomachs (Section 3.42) it is believed that filter feeding is more important than particulate feeding, if the latter exists at all. The adults also have fine gill rakers, plus a gizzard and a very long intestine (Section 1.31). This type of digestive tract has been found in several other species of fish, most of which have been observed to feed by stirring up mud from the bottom and ingesting it to obtain the detritus and minute organisms that it contains. The feeding of adult anchovetas has not been observed, but the stomachs nearly always contain mud and benthic diatoms, so it is believed that they also feed in this manner.

3.42 Food

Bayliff (1963a) studied the food of the anchoveta in the Gulf of Panama. Diatoms, particularly Coscinodiscus, Cyclotella, Actinoptychus, Biddulphia, Navicula, and Nitzschia, were the most important food of juvenile anchovetas, while silicoflagellates, dinoflagellates, and crustaceans were consumed in lesser amounts. No significant changes in the foods consumed with increase in size of the fish were detected. The most important identifiable organisms in the stomachs of the adults were also diatoms, especially Melosira, Coscinodiscus, Sceletonema, Actinoptychus, Biddulphia, Cyclotella, Thalassionema, Navicula, and Nitzschia. Melosira was the most important diatom in the stomachs of the fish taken east of the entrance of the Panama Canal, but occurred infrequently in those of the fish from the west of the entrance of the Canal. This diatom was abundant in mud samples from the former area, but much less common in those from the latter area. No other significant differences by area or time of year were found in the stomach contents. Schaefer (1954) reported Melosira in the stomachs of adult anchovetas from Almejas Bay and Coscinodiscus in the stomachs of those from the Gulf of Nicoya. The volumes of material in the stomachs of the adult fish studied by Bayliff ranged from almost none to nearly 1.0 ml, with an average of a little more than 0.2 ml.

3.43 Growth rate

The growth of the anchoveta has been determined from length-frequency data. In Table V are shown data on its growth in 9 localities, as given by Bayliff (1967). He gave the constants l_∞ and K of the von Bertalanffy growth equation, but omitted t_0 because he believed that the sketchy knowledge of when the spawning occurs in most areas and the paucity of length-frequency data for the smaller fish render the validity of these estimates doubtful.

The growth of the anchoveta in the Gulf of Panama, as given by Bayliff (1967), is shown in Fig. 4. The growth is most rapid from January to June of the first year of life and January to April of the second and third years of life. This corresponds to the period of upwelling in that area, when the production of organic material is greatest (Forsbergh, 1963). The accelerated growth is apparently not the direct result of upwelling, however, for Bayliff (1964) pointed out that the period of accelerated growth sometimes takes place earlier or later than usual when the upwelling takes place at the usual time. The period of accelerated growth of the older fish occurs shortly after spawning, but Bayliff (1964) showed that it is apparently not related to the time of spawning either.

Bayliff (1964) found significant and near-significant negative relationships between the mean lengths of the young of the year in the Gulf of Panama during July through November and the sea-surface temperatures and sea levels during the previous periods of upwelling, indicating that greater-than-average upwelling produces larger-than-average fish. He also found a near-significant positive relationship between the size of the fish and the size of the population of anchovetas in the Gulf of Panama, as measured by the catch per unit of effort (Section 4.21) during February, March, and April. He believed that some environmental factor was the common cause of the greater size of the population and of the individual fish, rather than that the greater size of the population caused the fish to grow larger, or vice versa.

In 1961 and 1962 the anchovetas in the Gulf of Panama were much larger than usual (Bayliff, 1964). In 1961 the principal components of the population were the young of the year of the 1960 year class and the 1-year-olds of the 1959 year class. The latter had been of normal size in 1960, but were larger than average in 1961. In 1962 the 1-year-olds of the 1960 year class

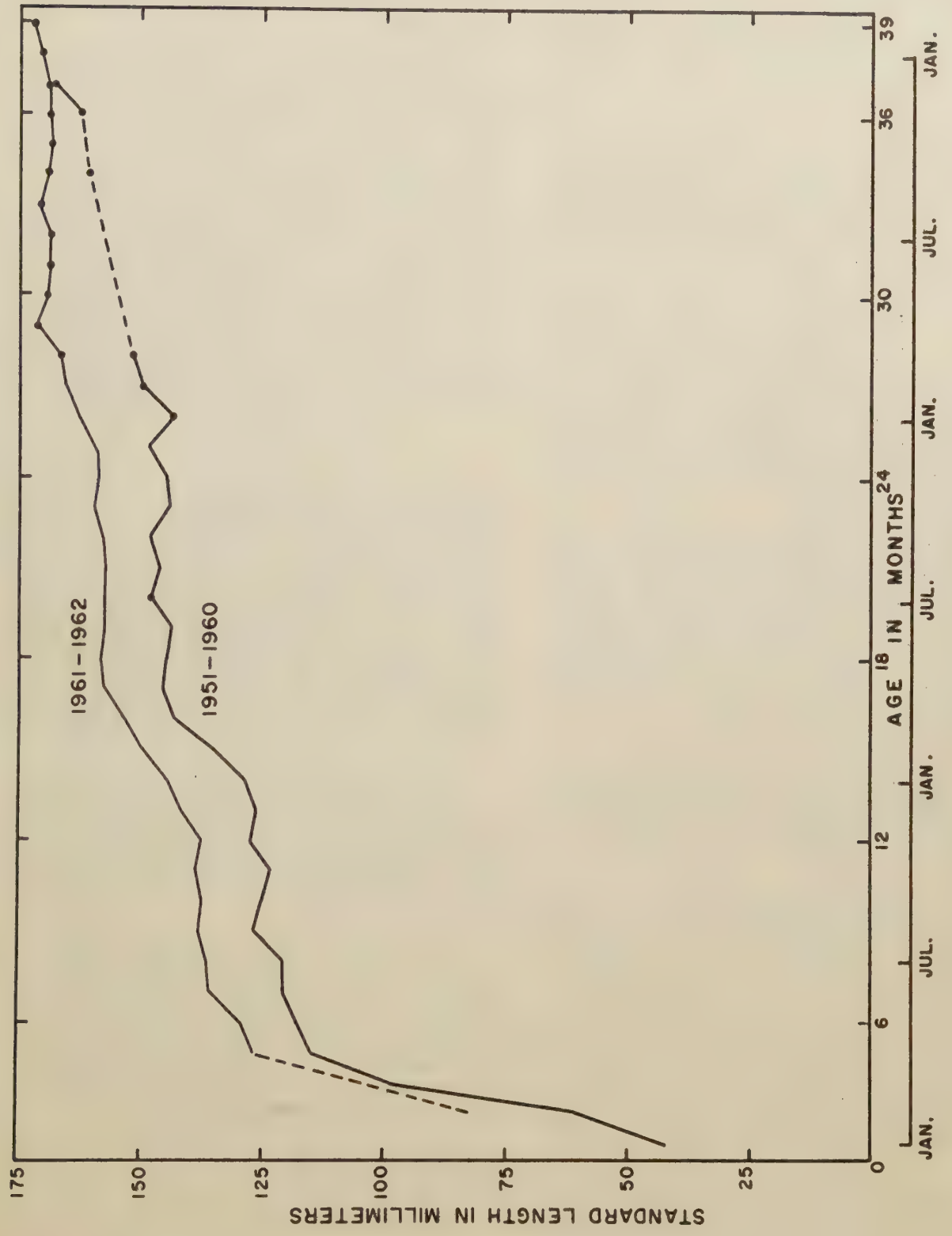


Figure 4. Growth of the anchoveta in the Gulf of Panama. The open circles indicate the mean lengths based on less than 30 fish.

were no larger than had been the 1-year-olds of the 1959 year class in 1961, even though the 1960-year class fish had been exposed to two years of what are presumed to have been good growing conditions, while the 1959-year class fish had been exposed to only one.

3.44 Metabolism

Von Bertalanffy (1934) has shown that K in his growth equation is very close to the rate of nitrogen excretion of starving animals. Therefore the estimates of K in Table V are indices of the rate of catabolism of the anchoveta. These are exceptionally high values of K for fish.

3.5 Behaviour

3.51 Migrations and local movements

Adult anchovetas have been found only over mud flats, and it is unlikely that they make long migrations along sandy or rocky shores from one suitable area to another. It is also unlikely that the juveniles make such migrations, as they have not been observed far from areas with mud flats.

The tagging experiments of Bayliff (1966) provide some information on the migrations of the anchoveta in the Gulf of Panama. These data are summarized in Table VI. The only areas where there was fishing were Isla Verde (Punta Chame to the entrance of the Panama Canal) and Panama Viejo, so no returns of tags were made from the other areas. In general, there was not much interchange of fish among areas within the Gulf of Panama.

Fish tagged at Bahia Parita appeared at Isla Verde as soon as 31 days after tagging, and a relatively large number of these appeared in that area. These fish had to migrate about 60 km over sandy bottom to get from Bahia Parita to Isla Verde.

Very few fish from the areas to the east of the entrance of the Panama Canal migrated to Isla Verde. There is a jetty just east of the entrance of the Canal which extends southward to a depth of about 10 m, and this possibly prevents most of the fish from migrating to Isla Verde. The majority of the tags from the fish which made this migration were returned in the season after tagging. From the temporal patterns of return of these tags it appears that there were migrations of older fish from these areas to Isla Verde in late May or early June of 1961 and late June or early July of 1962.

Little information is available on the migration of fish from Isla Verde to the other areas, as there was little or no fishing in those areas. Few Isla Verde tags were returned from Panama Viejo, even considering the low fishing effort there, so apparently few fish from Isla Verde migrate to Panama Viejo, except possibly temporarily during the spawning season (see below).

Simpson (1959) found the spawning in the Gulf of Panama in 1956-1957 and 1957-1958 to occur chiefly from the entrance of the Panama Canal to Punta de Brujas. Since anchovetas reside beyond this area during most of the year, these presumably migrated to the Panama Canal-Punta de Brujas area to spawn, and these or other fish presumably left the Panama Canal-Punta de Brujas area to repopulate the other areas after the spawning season. Since the tags returned from Isla Verde the season after tagging were mostly from fish tagged in that area it appears that either (1) the Isla Verde fish spawned in that area, rather than the Panama Canal-Punta de Brujas area, in 1960-1961 and 1961-1962, or (2) after the spawning season the Isla Verde area was repopulated chiefly by fish which had resided there before spawning.

3.52 Schooling

The schooling behaviour of the anchoveta has been discussed by Bayliff (1966). On the mud flats where it lives there are locations of greater and lesser concentrations of fish, which shift from day to day. The fishermen detect the presence of greater concentrations by the actions of predatory birds, "flipping" of the fish, and the slightly greater turbidity of the water. Distinct schools are not observed. When tagged fish were released together a discrete school was sometimes in evidence for a few minutes, but was never observed to remain in the immediate vicinity of the tagging vessel for a significant amount of time.

The schools are believed to break up and reform rather rapidly, for when tagged fish were released in schools on some occasions a few of the tagged fish were caught the same day by purse-seine vessels, while others of the same schools continued to be caught one or a few at a time for the next 2 years.

The anchoveta tends to school by size. In the Gulf of Panama young of the year and older fish are not usually caught in the same schools in April, May, or June (Bayliff, 1964), but as the season progresses they tend to mix more. The anchoveta has not been observed to school with other species, though a few small fish, mostly engraulids and clupeids, are usually caught with anchovetas in purse seines.

TABLE V

Growth of the anchoveta in different areas. The data are all from Bayliff (1967), or the references cited by him, except for the maximum recorded length for Ecuador-Peru, which was obtained from Ansaldo Garces (1964)

Area	Standard length in millimeters at age in months						l_∞	K	Maximum recorded length
	6	12	18	24	30	36			
Almejas Bay	101.6	121.2	146.4	153.6	-	-	166.0	1.23	170
Guaymas Bay	106.5	127.0	138.5	141.3	-	-	141.5	2.58	163
Ahome Point	109.3	131.7	140.0	144.4	-	-	145.7	2.42	164
Banderas Bay	90.6	-	111.4	-	-	-	105.6	2.30	137
Gulf of Fonseca, 1952	-	-	-	-	-	-	154.0	2.92	161
Gulf of Fonseca, 1951, 1954, 1955	-	-	-	-	-	-	170.8	0.90	166
Montijo Bay	99.5	149.4	152.0	-	-	-	159.1	2.42	170
Gulf of Panama, 1951-1960	117.5	127.2	144.3	144.5	-	162.0	149.5	2.36	170
Gulf of Panama, 1961-1963	129.0	137.4	157.6	158.1	169.0	168.6	169.8	1.31	175
Colombia	94.9*	126.7*	138.4*	137.5*	-	-	143.1	2.09	156
Ecuador-Peru	95.5	117.8	-	136.0	-	-	144.8	1.34	162
Mean							150.0	1.99	

* lengths at 5, 11, 17, and 23 months, respectively.

TABLE VI

Releases and returns from the tagging experiments conducted with anchovetas in the Gulf of Panama

Released		Returned						
		1960 season		1961 season		1962 season		Total
Area and date	Number	Isla Verde	Panama Viejo	Isla Verde	Panama Viejo	Isla Verde	Panama Viejo	
Isla Verde								
1960	15,370	737	0	190	1	7	0	935
1961	61,272	-	-	346	2	34	0	382
Bahia Parita								
1961	9,399	-	-	21	0	4	0	25
Panama Viejo								
1960	11,721	1	5	29	3	1	0	39
1961	9,073	-	-	3	0	2	0	5
Rio Pacora								
1960	2,192	0	0	0	0	0	0	0
1961	3,350	-	-	1	2	0	0	3
Isla Chepillo								
1960	10,882	1	0	8	0	0	0	9
1961	5,534	-	-	0	0	0	0	0
Punta Mangle								
1960	6,629	0	0	7	0	0	0	7
1961	9,086	-	-	1	0	3	0	4
Isla Maje								
1961	8,847	-	-	1	0	5	0	6
Bahia San Miguel								
1960	6,586	1	0	7	1	0	0	9
1961	6,641	-	-	0	0	0	0	0
Total								
1960	53,380	740	5	241	5	8	0	999
1961	113,202	-	-	373	4	48	0	425

4 POPULATION

4.1 Structure

4.11 Sex ratio

The numbers of anchovetas of each sex sampled in various areas are shown in Table VII. The females outnumbered the males in eight of the nine areas, but the sex ratios varied considerably from month to month within the areas, with males sometimes predominating. There were no apparent seasonal patterns in the sex ratios. Bayliff (1963b) reported that there were 39 males and 106 females among 144 fish sampled at Panama Viejo, an important spawning area of the Gulf of Panama, during the peak of the 1958-1959 spawning season.

4.12 Age composition

Anchovetas are first captured by the tuna-bait fishery in the Gulf of Panama in January of their first year of life (Bayliff, 1964), when they are about 2 months old. The age of entry to the tuna-bait fishery in other areas is about the same. Anchovetas first enter the Gulf of Panama purse-seine fishery in March, April, or May of their first year of life, at about 4 or 5 months of age.

Data on the age composition of the anchoveta in different areas, as given by Bayliff (1967), are shown in Table VIII. Only data for the months for which the samples included no juvenile fish are shown, as the juvenile fish have a different mode of life (Section 2.2), and the adults and juveniles cannot be sampled in representative proportions by the same gear. The groups in the table include more than one age group, because in some cases the anniversaries of the fishes' hatching occurred during the periods indicated in the table. In the Gulf of Panama, for instance, spawning occurs principally in November and December, so the fish in the youngest group are considered to be 0+ years old from May through November and 1+ years old in December and January. It is believed that a few fish of the 2+ and 3+ age group occurred in the areas other than the Gulf of Panama, but that their presence could not be detected because of the small samples (Bayliff, 1967). Except for this, these data are believed to be reasonably indicative of the actual age composition of the adults of the population.

In Table IX are shown data on the age composition of the anchovetas from the Gulf of Panama sampled from June 1961 to March 1963 (Bayliff, 1964). The majority of these were caught by the purse-seine fishery, and the age composition of those caught by other methods did not appear to be different. Apparently in some months (i.e. June 1962) the sampling was biased but, as indicated above, the combined samples for May through January probably give a reasonable indication of the actual age composition of the adults of the population.

4.13 Size composition

Anchovetas are about 50 mm and 115 mm in standard length when they enter the tuna-bait fishery and the Gulf of Panama purse-seine fishery, respectively (Bayliff, 1967).

Figure 5 shows the length compositions of the fish sampled by Howard and Landa (1958) and Bayliff (1964) in the Gulf of Panama. The fish are roughly the same size in the other areas (Table V), but not necessarily in the same months because of differences in the times of spawning. Additional length-frequency histograms are given by Howard and Landa (1958), Barrett and Howard (1961), Bayliff (1963b, 1964, 1967), and Ansaldo Garces (1964).

The maximum lengths of individual fish recorded in various areas are listed in Table V.

Data on the length-weight relationships of the anchoveta in the Gulf of Panama are given by Bayliff (1965). He showed that significant differences in the length-weight relationships existed among fish collected in different months and areas and among fish of different ages. For this reason he did not combine the data for the different strata. When the weighted averages of the constants of the equations for the different months are calculated for the fish from Isla Verde the equations are:

1953 and 1954 year classes

younger (February through November)
$$\log_{10} w = -5.2679 + 3.2567 \log_{10} l$$

older (December through December)
$$\log_{10} w = -3.6881 + 2.5126 \log_{10} l$$

1960 and 1961 year classes

younger (April through November)
$$\log_{10} w = -5.9440 + 3.5504 \log_{10} l$$

older (December through March)
$$\log_{10} w = -4.4641 + 2.8767 \log_{10} l$$

where w = weight in grams and l = standard length in millimeters.

4.2 Abundance and density

4.21 Average abundance

Alverson and Shimada (1957) used catch per unit of effort as an index of abundance of the anchoveta. They recorded the catches of baitfish, including anchovetas, and the numbers of days devoted to fishing for them, by tuna vessels of six size classes. Any day which was devoted wholly or partly to fishing for baitfish was defined as 1 day's fishing, except when during a single day time was spent fishing for both baitfish and tunas, in which case ½ day was recorded as being devoted to each type of fishing.

TABLE VII

Sex ratios of the anchoveta in different areas

Area	Number		Percent		Reference
	Males	Females	Males	Females	
Almejas Bay	265	391	40	60	Barrett and Howard, 1961
Guaymas Bay	256	414	38	62	Ibid.
Ahome Point	120	194	38	62	Ibid.
Gulf of Fonseca	113	116	49	51	Ibid.
Chiriqui Province	42	47	47	53	Bayliff, 1963b
Montijo Bay	908	1257	42	58	Ibid.
Gulf of Panama	738	688	52	48	Howard and Landa, 1958
Colombia	140	160	47	53	Barrett and Howard, 1961
Gulf of Guayaquil	411	549	43	57	Barrett and Howard, 1961; Ansaldo Garces, 1964

TABLE VIII

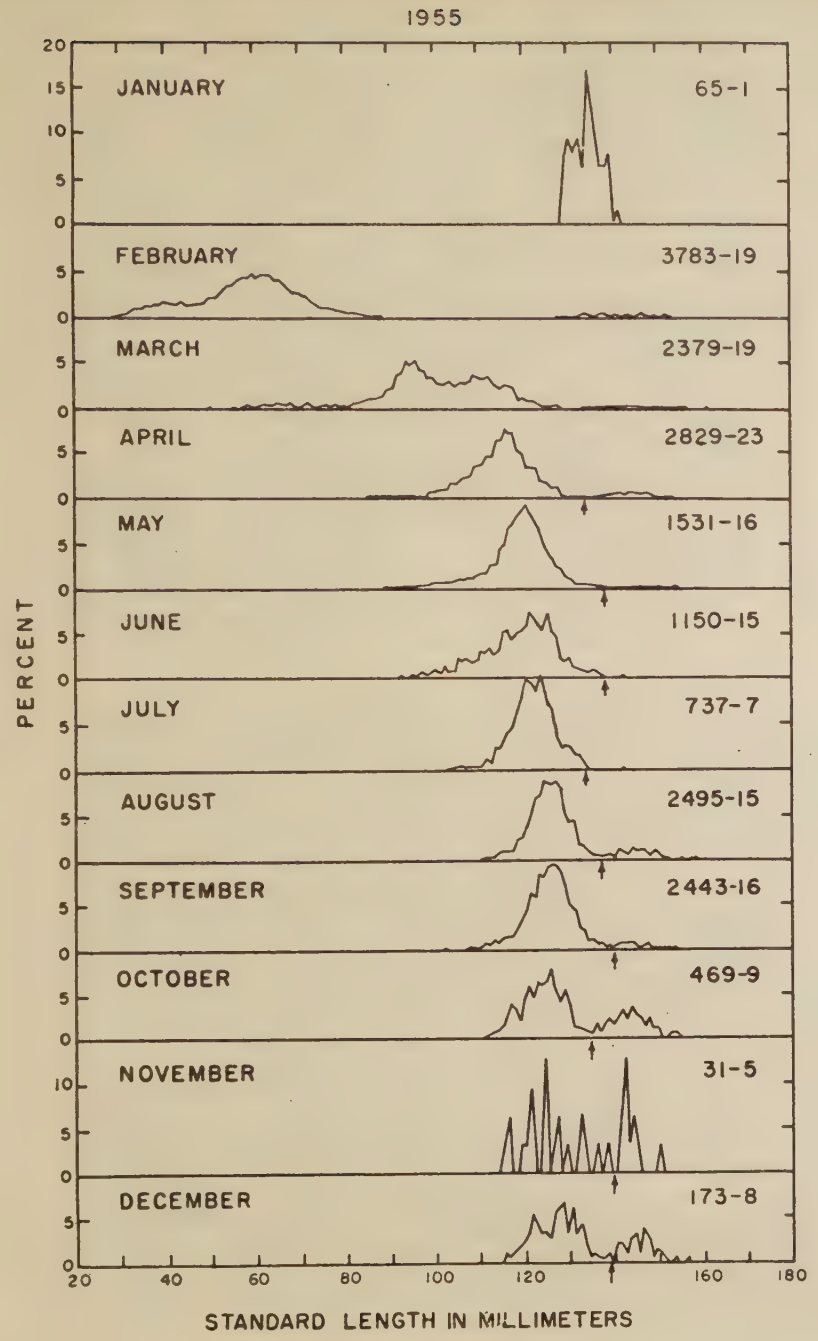
Age composition and coefficients of annual total mortality (Z) of the anchoveta in different areas

Area	Months included	Age group			Z
		0+ and 1+	1+ and 2+	2+ and 3+	
Almejas Bay	November–May	10,199	1,299	–	2.18
Guaymas Bay	April–October	4,096	1,271	–	1.44
Ahome Point	March–August	3,250	655	–	1.79
Banderas Bay	March–May	1,853	126	–	2.75
Gulf of Fonseca, 1952	May–December	775	76	–	2.42
Gulf of Fonseca, 1951, 1954, 1955	May–December	1,500	101	–	2.76
Montijo Bay	June–February	1,860	87	–	3.11
Gulf of Panama, 1951–1960	May–January	19,830	1,094	23	2.96
Gulf of Panama, 1961–1963	May–January	24,019	2,346	62	2.45
Colombia	June–January	1,041	140	–	2.13
Ecuador–Peru	June–January	2,287	148	–	2.80
Mean					2.44

TABLE IX

Numbers and percentages of anchovetas in their first, second, third, and fourth years of life measured in the Gulf of Panama during each month from June 1961 through March 1963

Year	Month	Number of fish	Fish in first year		Fish in second year		Fish in third year		Fish in fourth year	
			Number	Percent	Number	Percent	Number	Percent	Number	Percent
1961	June	2,245	1,924	85.7	307	13.7	14	0.6	0	0.0
	July	2,319	2,071	89.3	236	10.2	12	0.5	0	0.0
	August	1,164	941	80.8	212	18.2	11	0.9	0	0.0
	September	1,165	987	84.7	177	15.2	1	0.1	0	0.0
	October	1,068	981	91.9	81	7.6	6	0.6	0	0.0
	November	734	695	94.7	38	5.2	1	0.1	0	0.0
	December	1,466	0	0.0	1,415	96.5	51	3.5	0	0.0
1962	January	1,440	0	0.0	1,430	99.3	10	0.7	0	0.0
	February	456	0	0.0	449	98.5	7	1.5	0	0.0
	March	0								
	April	1,396	620	44.4	774	55.4	2	0.1	0	0.0
	May	1,625	1,426	87.8	198	12.2	1	0.1	0	0.0
	June	1,971	1,965	99.7	6	0.3	0	0.0	0	0.0
	July	2,449	2,337	95.4	112	4.6	0	0.0	0	0.0
	August	1,832	1,558	85.0	273	14.9	1	0.1	0	0.0
	September	1,865	1,457	78.1	404	21.7	4	0.2	0	0.0
	October	1,315	1,280	97.3	35	2.7	0	0.0	0	0.0
	November	1,535	1,447	94.3	84	5.5	4	0.3	0	0.0
	December	1,218	0	0.0	1,127	92.5	85	7.0	6	0.5
1963	January	1,016	0	0.0	978	96.3	37	3.6	1	0.1
	February	1,013	0	0.0	985	97.2	26	2.6	2	0.2
	March	577	0	0.0	565	97.9	12	2.1	0	0.0



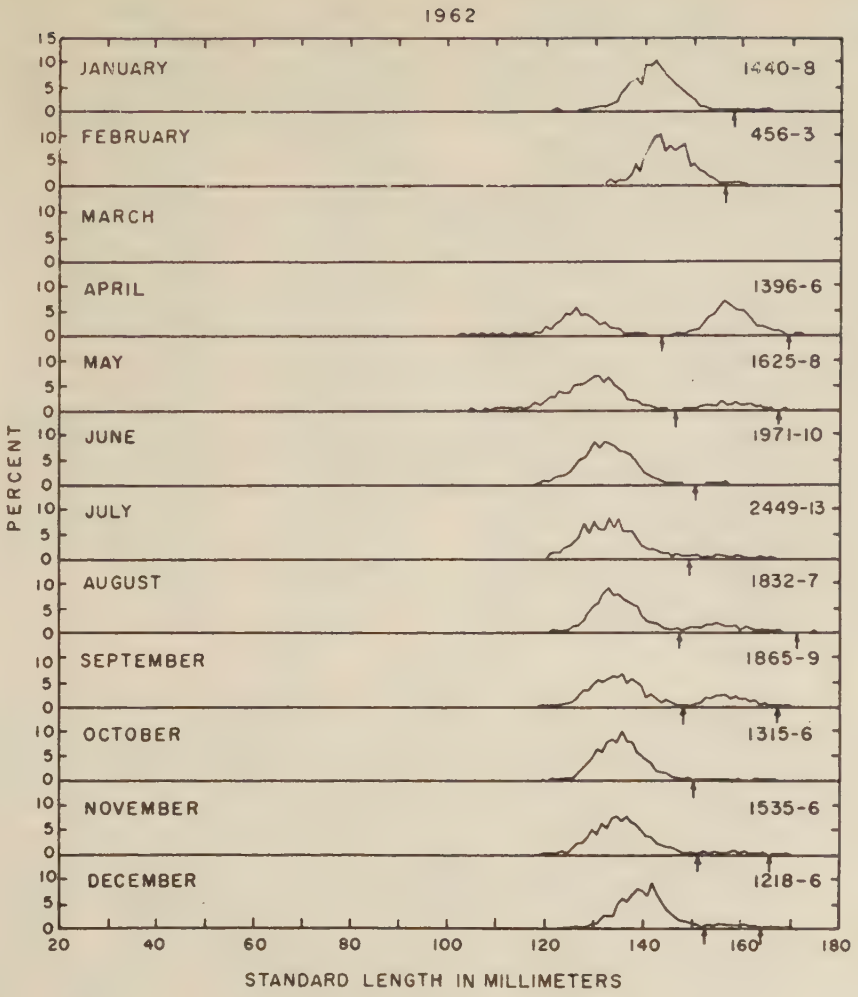


Figure 5. Length-frequency distributions of anchovetas collected in the Gulf of Panama in 1955 and 1962. The vertical arrows between the modes separate what are considered to be different age groups. The numbers at the right side of each panel indicate the numbers of fish measured and the numbers of samples taken each month, respectively.

From these data they calculated the catch per day's fishing, standardized to Class-4 vessels (181-272 metric tons capacity) (Table X). It is believed that the best index of abundance of the fish is the time spent actually looking for schools of fish, and not including the time spent setting the net or transferring the fish from the net or receiver to the vessel. For example, when the fish are very abundant very little time would be spent locating a school, but it would take about the same amount of time to load the same amount of fish aboard the vessel as when the fish were scarce. Thus the differences in abundance from year to year are probably greater than indicated by Alverson and Shimada's method.

The purse-seine vessels fishing for anchovetas and thread herring in the Gulf of Panama make one, or sometimes two, fishing trips per day. Thus a trip could be considered as 1 unit of effort, and the catch per unit of effort would be the catch per trip. Bayliff (1966), however, believed that the catch per trip (which he referred to as the "catch per landing") was not a valid index of the abundance of the fish during the period of his investigations (1956-1963). The fish were relatively easy to catch during a considerable portion of the year, so the vessels tended to land amounts of fish corresponding to their capacities, rather than to the abundance of the fish. The time spent away from port also would not be a valid measure of the effort, as the more important of the two reduction plants was accessible to the vessels only near the time of high tide, so the fully-loaded vessels often had to wait several hours for the tide to rise, and when fish were scarce vessels sometimes had to return to port before they were fully loaded in order to unload when the tide was high. In addition, during that period the fleet was composed of a small number of vessels of considerable variety (Section 5.12), and their turnover rate was high. Many of these broke down frequently, and all of them were inadequately equipped. The captains and crews were inexperienced, at least with anchovetas, and their turnover rate was high too. It is apparent that under these circumstances a valid measure of effort cannot be devised.

It is believed that a valid measure of effort will not be obtained until there has developed a fleet of vessels of one or a few types with experienced captains and crews. If the vessels and/or the ancillary fishing equipment are improved this must take place over a period of several years, and the changes must be documented, so that the effort can be standardized. If and when this situation comes into being the best measure of the effort will probably be the time spent searching for fish, as distinguished from the time spent travelling to and from the fishing grounds and the time spent setting the net and transferring the fish from the net to the hold of the vessel (Bayliff, 1966).

Bayliff (1966) estimated the size of the population of anchovetas of the 1959 year class at Isla Verde in the Gulf of Panama during the 1960 season (Fig. 6). Forsbergh (1969) used these data, plus data on the area of suitable habitat (mud bottom within the 5-fathom or 9.144-m curve) available in the Gulf of Panama, to estimate the populations of fish of all year classes at Isla Verde and in the entire Gulf of Panama in 1960 (Table XI). No estimates of the populations of anchovetas in the areas other than the Gulf of Panama have been made. Because of the larger area of the Gulf of Panama, and because larger catches have been made there by the tuna-bait fleet (Table XIII). It is believed that the population of anchovetas is greater there than in any other area.

4.22 Changes in abundance

Forsbergh (1963) found no relationship between the abundance of anchovetas in the Gulf of Panama, as measured by the catch per unit of effort by the tuna-bait fleet, and the amount of upwelling in that area.

Alverson and Shimada (1957) found no relationship between the catch per unit of effort and the fishing effort by the tuna-bait fleet for the anchoveta (Table X), and concluded that its abundance was not markedly affected by fishing. Bayliff (1966) showed that in 1960 the removals from the population of anchovetas at Isla Verde in the Gulf of Panama by fishing were considerably less than those due to natural mortality.

4.23 Average density

Table XI gives estimates of the population of anchovetas at Isla Verde in the Gulf of Panama in each month (Forsbergh, 1969). Howard and Landa (1958) state that adult anchovetas are found in water of 5 fathoms (9.144 m) or less. The volume of water in that area is estimated to be 1.51×10^9 m^3. From these data the densities in numbers and in grams of adult fish per cubic meter were estimated (Table XI).

4.3 Natality and recruitment

4.31 Reproduction rates

Forsbergh (1969) estimated the annual egg production by anchovetas from Isla Verde in the Gulf of Panama to be 2.33×10^{12} eggs. Since he estimated the population of anchovetas of the entire Gulf of Panama to be 8.2 times that of the Isla Verde area, the annual production for the entire Gulf of Panama would be about 1.91×10^{13} eggs. The 2.33×10^{12} eggs produced by the fish from Isla Verde yielded about 1.16×10^9 2-month-old fish in January 1960 (Table XI), so the survival from November to January is roughly 0.0005. Forsbergh (1969) pointed out, however, that his estimate of the population of

TABLE X

Catch per unit of effort, in metric tons per standard day's fishing, and calculated effort, in standard day's fishing, for anchovetas in five areas. The 1946–1954 data are from Alverson and Shimada (1957), while those for 1955–1960 are from unpublished data of the Inter-American Tropical Tuna Commission

	Almejas Bay		Guaymas Bay		Ahome Point		Gulf of Fonseca		Gulf of Panama	
	Catch per unit of effort	Effort	Catch per unit of effort	Effort	Catch per unit of effort	Effort	Catch per unit of effort	Effort	Catch per unit of effort	Effort
1946	1.028	102.0	1.887	354.0	1.469	110.5	1.215	119.0	1.088	20.0
1947	1.050	347.5	1.542	766.0	1.139	475.5	0.800	163.5	1.290	403.5
1948	1.491	532.5	-	0.0	1.822	660.5	0.109	32.5	1.657	866.0
1949	1.057	811.0	0.277	12.5	2.727	370.0	0.429	28.0	2.464	757.0
1950	2.118	854.3	2.975	587.0	2.456	121.0	1.288	52.5	1.291	515.5
1951	1.909	467.5	2.245	700.0	2.582	589.0	1.737	359.5	2.169	352.0
1952	1.638	828.5	2.278	931.5	1.309	201.0	1.909	544.0	2.238	1501.0
1953	2.175	578.9	2.718	475.0	2.734	219.5	0.540	36.5	1.530	1478.5
1954	2.227	166.0	3.008	530.5	3.237	128.0	1.912	90.5	1.926	1433.0
1955	2.735	380.1	3.120	262.3	3.149	182.5	1.736	137.7	1.475	999.2
1956	2.255	328.3	3.360	403.1	3.035	191.4	0.101	79.1	1.964	720.9
1957	2.170	43.8	3.800	204.2	2.750	638.5	0.000	4.5	2.123	1224.7
1958	2.363	605.1	1.052	22.6	0.030	5.5	0.000	4.7	2.244	644.7
1959	2.047	499.8	0.000	2.2	2.494	55.4	0.000	1.0	2.148	366.8
1960	1.829	248.9	-	0.0	-	0.0	0.000	1.0	2.157	366.1

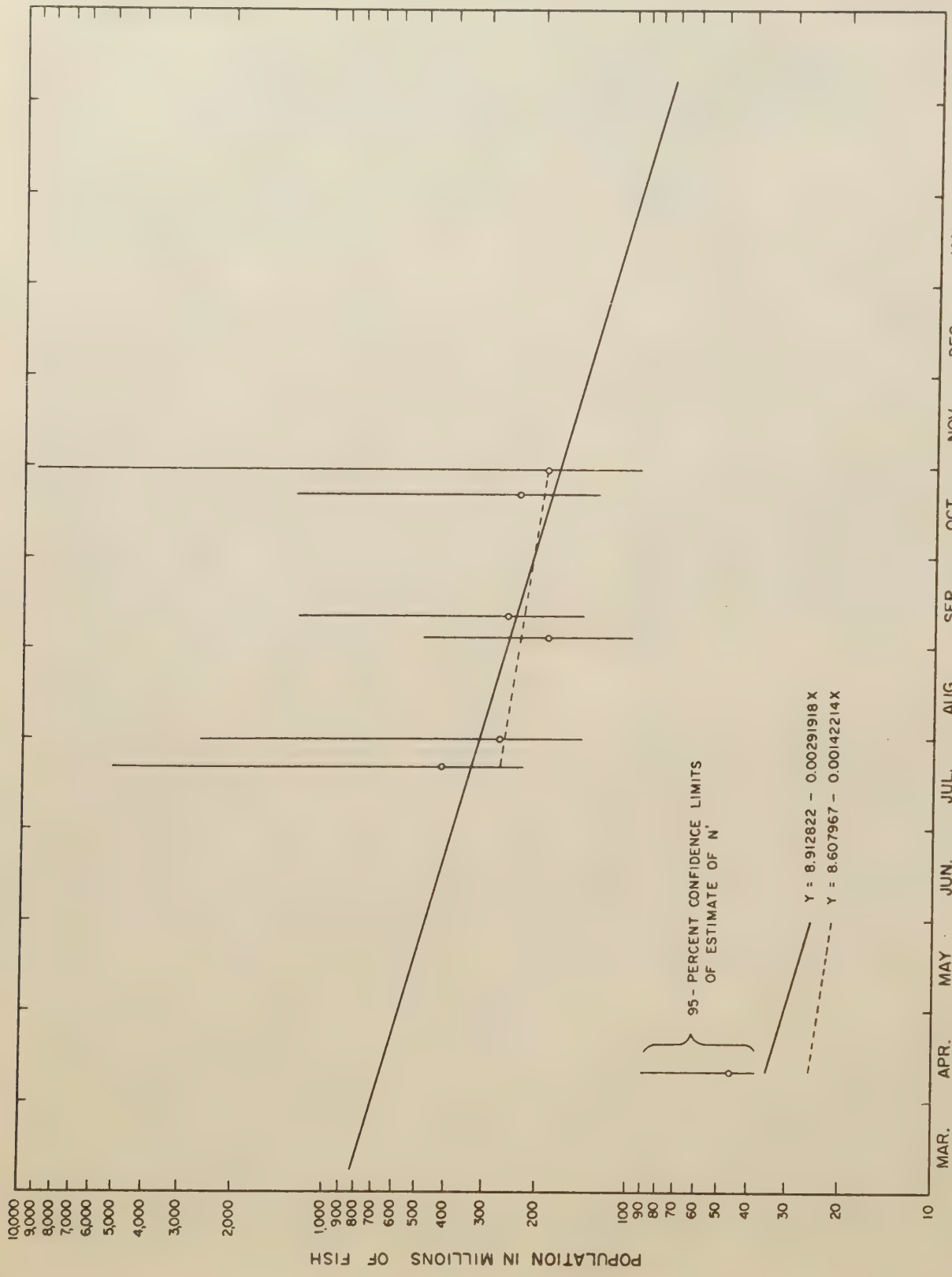


Figure 6. Population size ($\underline{N'}$) and survival of anchovetas of the 1959 year class at Isla Verde in the Gulf of Panama during the 1960 season. The dashed line is fitted to the six estimates of the population size. The solid line passes through the mean of the dashed line, while its slope corresponds to the estimated coefficient of annual total mortality of 2.45.

TABLE XI

Estimated populations of anchovetas at Isla Verde and in the entire Gulf of Panama during each month of 1960, as estimated from data on the population of 1959-year class fish at Isla Verde in 1960. The data in parentheses represent juvenile fish, and these are not included in the totals.

	1959 year class	1958 year class	1957 year class	1956 year class	All year classes	Gulf of Panama All year classes	All year classes
	Numbers of fish in thousands						Numbers of fish per cubic meter
January	(1,158,700)	99,110	8,510	730	108,350	888,470	0.07
February	(946,820)	80,960	6,980	600	88,540	726,028	0.06
March	774,150	66,580	5,730		846,460	6,940,972	0.56
April	630,720	54,230	4,660		689,610	5,654,802	0.46
May	514,410	43,980	3,800		562,190	4,609,958	0.37
June	418,570	35,990	3,100		457,660	3,752,812	0.30
July	341,380	29,320	2,520		373,220	3,060,404	0.25
August	277,160	23,800	2,050		303,110	2,485,502	0.20
September	225,530	19,390	1,670		246,590	2,022,038	0.16
October	183,930	15,800	1,350		201,080	1,648,856	0.13
November	149,670	12,870	1,100		163,640	1,341,848	0.11
December	122,070	10,480	900		133,450	1,094,290	0.09
	Weights of fish in metric tons						Grams of fish per cubic meter
January	(1,193)	3,515	471	54	4,040	33,128	2.68
February	(3,958)	4,390	415	44	4,849	39,762	3.21
March	12,947	4,176	377		17,500	143,500	11.58
April	16,670	3,512	369		20,551	168,518	13.61
May	13,704	2,635	297		16,636	136,415	11.02
June	11,506	2,005	240		13,751	112,758	9.11
July	9,934	1,568	192		11,694	95,891	7.74
August	8,722	1,319	155		10,196	83,607	6.75
September	7,075	1,129	124		8,328	68,290	5.52
October	5,641	841	97		6,579	53,948	4.36
November	4,746	713	76		5,535	45,387	3.67
December	4,116	602	66		4,784	38,259	3.17

young of the year for January was probably minimal, in which case the survival would be higher.

4.32 Factors affecting reproduction

Except for the amount of upwelling in the Gulf of Panama, discussed in Sections 3.16 and 4.22, there are no data concerning the factors affecting the success of reproduction of the anchoveta.

4.33 Recruitment

The recruitment of anchovetas to the tuna-bait and purse-seine fisheries takes place when the young of the year reach standard lengths of about 50 and 115 mm, respectively (Section 4.13). The first dates that the young of the year were caught by the purse-seine fishery during the period of Bayliff's (1966) study were March 8, 1960, April 26, 1961, March 12, 1962, and April 18, 1963.

Bayliff (1966) estimated that there were 8.2×10^8 recruits to the purse-seine fishery at Isla Verde in the Gulf of Panama in 1960. Since Forsbergh (1969) estimated that the population for the entire Gulf of Panama is about 8.2 times that of Isla Verde, the recruitment for the entire Gulf of Panama would be about 6.7×10^9 fish.

Most of the fish in the population are in their first year of life (Section 4.12), and fishing is not considered to have had an important effect on the population size during the period of the tuna-bait fishery (Section 4.22). Therefore the abundance of anchovetas is a good indication of the amount of recruitment. The catch per unit of effort (Section 4.21) provides a somewhat biased estimate of the abundance.

According to the data in Table X there is no apparent relationship between the recruitment (catch per unit of effort in a given year) and the stock size (catch per unit of effort in the preceding year).

4.4 Mortality and morbidity

4.41 Mortality rates

Estimates of the coefficients of annual total mortality of the anchoveta in various areas, as given by Bayliff (1967), are shown in Table VIII. Bayliff (1966) obtained the following estimates for the coefficient of annual total mortality of the fish at Isla Verde in the Gulf of Panama: Chapman-Robson method (pooled data for the 1961 and 1962 seasons), 2.45; year-class method (1959 year class), 2.28; Jackson positive method (1959 year class), 2.43. He believed the first estimate to be the best. His estimates of the coefficients of annual total mortality obtained from data for other years and for other year classes varied somewhat, and these differences are believed to be due chiefly to differences in recruitment and to sampling biases. He estimated the coefficient of annual natural mortality at Isla Verde to be 2.11, and the coefficient of annual fishing mortality to have ranged from 0.00 to 0.93 in different months of the 1960 season. The catch in the Gulf of Panama, and especially at Isla Verde, has increased considerably since 1960 (Table XII), so presumably the coefficient of annual fishing mortality has increased correspondingly. Bayliff (1967) assumed that the coefficients of annual fishing mortality in the areas other than the Gulf of Panama were negligible, and if this is the case the coefficients of annual natural mortality would be the same as the coefficients of annual total mortality shown in Table VIII.

4.42 Factors causing or affecting mortality

Predation (Sections 3.23 and 3.34) is believed to be the chief cause of mortality of juvenile and adult anchovetas. Fishing mortality is negligible except in the Gulf of Panama, and there it is less important than natural mortality.

4.5 Dynamics of the population

Alverson and Shimada (1957) examined catch, effort, and catch-per-unit-of-effort data for the tuna-bait fishery for anchovetas at Almejas Bay, Guaymas Bay, Ahome Point, the Gulf of Fonseca, and the Gulf of Panama (Table X). The catches per unit of effort did not decline in any of these areas during 1946 through 1954, a period during which the fishing effort increased considerably. They concluded that at such levels of effort there was no danger of these subpopulations being reduced to sizes below those which would produce the maximum sustainable yield.

Bayliff (1966) studied the population dynamics of the anchoveta in the Gulf of Panama. He used length-frequency and length-weight data to define an empirical growth-in-weight relationship. The fishing and natural mortality rates were estimated from length-frequency, tagging, and catch data. The coefficient of fishing mortality differed considerably in different months of the 1960 season, the one with which he was most concerned. Accordingly, he wrote a vector consisting of estimates of the coefficient of annual fishing mortality during each month of the 1960 season and multiplied this by a series of scalars or "multipliers" to indicate the effects of different amounts of fishing effort. For example, a multiplier of 1 indicated the same fishing effort and coefficients of fishing mortality as were encountered in the 1960 season, while a multiplier of 2 indicated fishing effort and coefficients of fishing mortality twice those of the 1960 season. Figure 7 shows the estimated yield per recruit at various combinations of fishing effort and times of entry into the fishery.

TABLE XII

Catches of anchovetas and thread herring in metric tons by the purse-seine fleet of Panama. The numbers at the heads of the columns correspond to the numbers of the areas shown in Fig. 3. Anchovetas and thread herring were not distinguished from one another for the statistics of 1964 or 1965, so the quantities listed as anchovetas for those years actually represent both genera. The 1956–1962 data were collected by the Inter-American Tropical Tuna Commission, and those of 1963–1967 by the Departmento de Pesca of Panama

	1956 Total	1957 Total	1958 Total	1959 1	2	3	4	Total	1960 1	2	Total
Anchovetas											
January	0	0	51	0	0	0	0	0	3	0	3
February	0	0	0	10	0	0	0	10	14	225	239
March	0	0	142	38	0	0	0	38	16	88	104
April	8	0	138	1738	0	2	0	1740	595	6	601
May	9	91	91	1286	0	0	0	1286	126	5	131
June	81	91	26	1199	6	0	0	1205	18	99	117
July	213	0	30	1284	0	0	0	1284	445	162	607
August	165	95	0	723	0	0	23	746	654	38	692
September	0	214	0	940	0	0	0	940	574	3	577
October	0	189	0	174	0	0	0	174	192	0	192
November	0	27	0	0	0	0	0	0	27	0	27
December	0	33	7	13	0	2	0	15	148	0	148
Total	476	740	485	7405	6	4	23	7438	2811	625	3436
Thread herring											
January	0	0	0	0	3	4	0	6	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	4	0	0	0	4	0	0	0
May	0	0	0	0	0	0	0	0	5	0	5
June	0	0	0	0	0	0	0	0	0	0	0
July	0	136	70	0	0	0	0	0	0	0	0
August	23	1	127	133	0	0	0	133	149	0	149
September	161	26	33	217	0	0	0	217	153	0	153
October	161	308	337	399	0	0	0	399	245	0	245
November	23	430	458	512	0	0	0	512	469	0	469
December	5	93	197	35	0	64	0	98	34	0	34
Total	374	995	1221	1299	3	67	0	1369	1057	0	1057

TABLE XII (continued)

	1961			1962			1963			1964	1965
	1	2	Total	1	2	Total	1	2	Total	Total	Total
Anchovetas											
January	191	42	233	159	247	406	598	8	605	746	1522
February	57	10	67	74	47	122	429	0	429	633	1928
March	0	9	9	306	0	306	564	0	564	875	2377
April	120	0	120	460	0	460	341	0	341	1276	1611
May	610	61	671	837	0	837	0	0	0	1904	2980
June	842	0	842	805	0	805	826	0	826	2682	2306
July	893	0	893	1103	0	1103	584	0	584	2861	3902
August	1275	0	1275	1338	0	1338	642	0	642	2028	4529
September	742	0	742	1240	0	1240	410	0	410	1752	4372
October	539	0	539	289	1	290	276	30	307	1328	2282
November	171	0	171	615	0	615	42	0	42	948	1876
December	388	0	388	673	0	673	62	378	440	1257	3275
Total	5829	122	5950	7899	295	8194	4775	416	5191	18290	32960
Thread herring											
January	0	0	0	0	0	0	0	0	0		
February	0	0	0	0	0	0	0	0	0		
March	0	0	0	0	0	0	0	0	0		
April	0	0	0	0	0	0	0	0	0		
May	0	0	0	0	0	0	0	0	0		
June	11	0	11	2	0	2	22	0	22		
July	18	0	18	0	0	0	130	0	130		
August	160	0	160	0	0	0	214	0	214		
September	193	0	193	26	0	26	432	0	432		
October	226	0	226	290	1	291	400	0	400		
November	570	0	570	99	0	99	831	0	831		
December	66	0	66	0	0	0	256	0	256		
Total	1244	0	1244	417	1	419	2285	0	2285		

TABLE XII (continued)

	1966 Total	1967 1	2	3	3a	4	5	Total
Anchovetas								
January	3899	33	775	838	843	2	0	2491
February	2963	27	16	21	816	53	0	933
March	2507	145	<0.5	0	2462	0	11	2618
April	4430	2697	1138	2958	600	0	0	7393
May	6927	2891	3969	2987	620	0	0	10467
June	8304	4535	616	1414	291	2	0	6858
July	9850	1178	1060	756	1072	0	0	4066
August	6676	286	217	111	28	23	35	699
September	2357	103	153	15	0	0	0	271
October	840	67	17	517	0	1	0	603
November	1474	20	0	309	6	0	0	335
December	2917	4	15	240	528	0	0	787
Total	53143	11987	7976	10167	7265	81	45	37521
Thread herring								
January	0	80	118	150	55	30	0	432
February	0	367	31	55	47	<0.5	0	500
March	0	22	9	326	142	0	11	509
April	0	221	60	135	28	0	0	444
May	0	5	0	0	0	0	0	5
June	0	759	8	76	0	8	0	851
July	416	1520	12	7	0	54	0	1593
August	1236	1750	41	<0.5	18	5070	0	6880
September	3282	1702	137	558	<0.5	2751	36	5183
October	4436	3427	26	813	11	1734	0	6011
November	2278	2031	96	716	22	186	0	3051
December	1224	625	3	900	172	13	0	1713
Total	12873	12508	541	3736	495	9846	47	27173

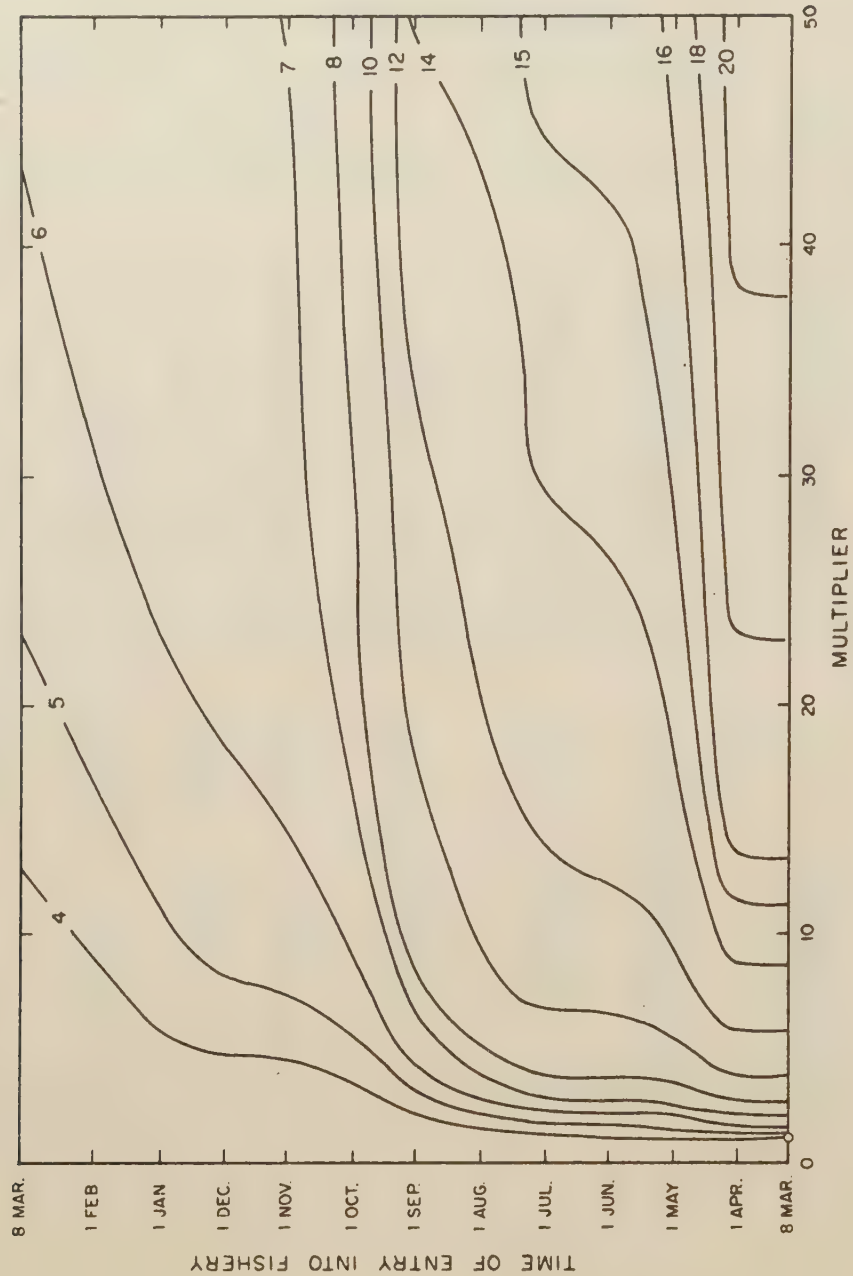


Figure 7. Yield per recruit in grams theoretically obtainable from any intensity of fishing up to 50 times that in effect during the 1960 season and for any time of entry into the fishery of the youngest age group to the end of the first season. The small circle on the abscissa represents the status of the fishery during the 1960 season.

This diagram indicates that beginning the fishery for the youngest age group later than March 8 (the date it began in 1960) would reduce the yield per recruit, while increasing the fishing effort would greatly increase it.

The yield-per-recruit approach does not take into account the possibilities that reduction in the number of spawners due to increased fishing effort may reduce the numbers of recruits in subsequent years, that the growth and/or mortality may be affected by the population size, or that reduction of the size of the population may subject it to displacement by competitors. Therefore it should not be assumed that the yields would be proportional to the yields per recruit shown in the isopleth diagram, especially at conditions of effort and time of entry considerably different from those in effect at the time Bayliff's study was made.

4.6 The population in the community and the ecosystem

The anchoveta feeds chiefly on diatoms and detritus (Section 3.42), and yet is large enough to be preyed upon by large predatory fish and birds (Section 3.34) and by man. Because this shortening of the food chain results in high production of food for these predators, it is an especially valuable fish to them.

Smayda (1966) presented some data on phytoplankton-anchoveta relationships for the upwelling season in the Gulf of Panama, when juvenile anchovetas are phytoplankton feeders. He estimated that the average standing crops of juvenile anchovetas and of phytoplankton were 26,400 and 5,434 mg of carbon per square meter, respectively. Each day the fish consumed a total of 955 mg of carbon per square meter, 619 mg of this being used for respiration and 336 for growth. The anchovetas consumed 17.6% of the standing crop of phytoplankton daily, and increased their own weight by 1.3% daily.

5 EXPLOITATION

5.1 Fishing equipment

5.11 Gears

Cast nets are employed for catching anchovetas for bait for the small local fisheries of some areas.

Anchovetas are caught for bait for the large tuna vessels with lampara nets, which range from about 150 to 270 m in length (Godsil, 1938; Scofield, 1951; Alverson and Shimada, 1957; Sundstrom, 1957).

The purse seines which are used for the reduction fishery in the Gulf of Panama are about 350 to 475 m long, 28 to 45 m deep, and constructed of 5/8- to 1-inch (1.59- to 2.54-cm) stretch synthetic netting, with narrow strips of 2-inch (5.08-cm) stretch netting adjacent to the corkline and leadline.

5.12 Boats

Cast netting is conducted chiefly from log canoes about 3 to 8 m in length. These are powered by outboard motors of about 5 to 50 hp, or sometimes only by paddles. The fish are kept alive in a live well at the centre of the canoe. Live-bait fishing may be conducted from the canoe or from a larger vessel.

A speedboat and two skiffs are employed for lampara-net fishing. The speedboat is about 6 m long, and is powered by a small inboard gasoline engine. The larger skiff, used for carrying the net, is about 6 m long, while the smaller skiff, to which the end of the net is attached when it is being set around a school of fish, is about 4 m long. Neither skiff is powered, except by oars. After capture the fish are kept alive in wells aboard the tuna vessel, which ranges in length from about 12 to 40 m (Godsil, 1938; Scofield, 1951; Alverson and Shimada, 1957; Sundstrom, 1957).

During the 1963-1967 period purse-seine vessels of the following gross metric tonnages were used to fish for anchovetas in the Gulf of Panama: 1-9 tons, 1 vessel; 10-36 tons, 3 vessels; 37-63 tons, 15 vessels; 64-82 tons, 7 vessels; 83-109 tons, 2 vessels. Omitting the one very small vessel, which fished for only a few months in 1964, some of the other properties of the vessels were as follows: length, 15 to 22 m; beam, 4.0 to 6.2 m; draft, 1.2 to 3.3 m; horsepower, 110 to 225. Most of the vessels are constructed of wood, and the remainder of steel. The skiffs are about 5 to 8 m in length, constructed of wood, and powered by 28- to 40-hp outboard motors.

During the earlier years of the purse-seine fishery the vessels tended to be smaller, and in some cases the skiffs were not powered except by oars. Power blocks were first used on a few of the vessels in 1966. An echo sounder was installed on one vessel in 1967.

5.2 Fishing areas

5.21 General geographical distribution

The areas where the anchoveta has been caught for use as tuna bait are listed in Table XIII. The locations of these areas are shown in Fig. 2 and Table III. It is probably used in small amounts for local bait fisheries in a few areas not listed in Table XIII. It is caught for reduction only in the Gulf of Panama, in Magdalena Bay and possibly a few other areas in Mexico, and near Tumaco, Colombia. It is caught for canning only in the aforementioned areas of Mexico and near Tumaco.

5.22 Geographic ranges

Anchovetas are usually caught within about 8 km of shore. The area of greatest abundance of this species is the Gulf of Panama, and other important areas are Alemjas Bay, Guaymas Bay, Ahome Point, and the Gulf of Guayaquil. The tuna fishery of the eastern Pacific Ocean is based chiefly in Southern California. It began in the early 1900's off Southern California and northern Mexico, so the anchovetas at Almejas Bay, Guaymas Bay, and Ahome Point were fished for bait first. As the tuna fishery gradually extended southward during the 1930's and 1940's the anchovetas in the more southern areas were exploited.

The fishery for anchovetas for bait is conducted in all parts of the Gulf of Panama in which fishing is permitted (Section 6.12), except along a stretch of sandy beach about 50 km in length between Bahia Parita and Punta Chame. Considerable fishing is conducted just south of Punta Chame, however. The purse-seine fishery for anchovetas for reduction in the Gulf of Panama was carried out almost entirely at Isla Verde and Panama Viejo, particularly the former, until 1964. This was primarily because the reduction plants were located in the Isla Verde area, and it was seldom necessary to travel far from there to catch fish. During the 1964-1967 period the range of the fishery was gradually extended to all parts of the Gulf of Panama, but the vessels do not go southeast of Puna Mangle except when fish cannot be caught elsewhere. Considerable fishing takes place to the southwest of Punta Chame, but the catch there consists almost entirely of thread herring.

5.23 Depth ranges

Juvenile anchovetas occur at the surface in water of depths to about 60 m. The adults are found from the bottom to the surface in water to about 5 fathoms (9.144 m).

5.24 Conditions of the grounds

Juvenile anchovetas usually live in relatively clear water, while the water of the mud flats where the adults live is turbid.

5.3 Fishing seasons

The anchoveta can be fished during the entire year. Little or no significance should be attached to the seasonal variations in the catch by tuna vessels, as no attempts are made to catch anchovetas for bait when tunas are not nearby. Also, the taking of anchovetas has been prohibited by law in some months in at least one area (Section 6.12).

Table XII shows the catches by months of anchovetas and thread herring by the purse-seine fishery of the Gulf of Panama. The fishing season was considered by Bayliff (1966) to begin when the young of the year became large enough (about 115 mm standard length) to be caught without becoming gilled in the meshes of the nets. This occurs in March or April. Good catches are made from then until about September or October, at which time the catch decreases. In November the catches are lowest, but they increase again in December and January. In September, October, November, and December of some years, because of the scarcity of anchovetas, the effort has been concentrated on thread herring, Opisthonema spp., which occur in somewhat deeper water. The period of scarcity of anchovetas corresponds to the period of their spawning, and it is believed that the fish become less available or less vulnerable because of some change in their behaviour or distribution associated with spawning. In February and March anchovetas again become scarce, and fishing may cease at that time in order to repair the plants and vessels for the next season.

5.4 Fishing operations and results

5.41 Effort and intensity

This subject is discussed in Section 4.21. The decline of effort by tuna vessels after 1958 (Table X) is the result of the conversion of most of the tuna vessels to purse-seiners.

5.42 Selectivity

The average standard lengths of anchovetas at entry into the tuna-bait and purse-seine fisheries are about 50 and 115 mm, respectively (Section 4.13). Smaller fish tend to get gilled in the meshes of the nets. Larger fish are avoided by tuna fishermen, as they are known to survive poorly in captivity.

5.43 Catches

Tables XII and XIII show the estimated annual catches of anchovetas by the purse-seine fishery of the Gulf of Panama and the tuna-bait fishery. In Table XIII the 1946-1956 data include only California-based vessels, those for 1957-1958 include also Puerto Rico-based vessels, and those for 1959-1966 include also Mexico-, Costa Rica-, Panama-, and Peru-based vessels. The great majority of the baitboat fleet has always been based in California, however, so it makes little difference whether data for vessels based in other areas are used or not. The decline in the catch of anchovetas by the tuna fleet after 1958 was the result of the conversion of most of these vessels to purse seiners. No data are available for the anchovetas caught for reduction in Magdalena Bay and possibly other areas, for those used for the live-bait fisheries other than that for tuna, for those which are canned in Mexico, Colombia, and possibly other countries, or for those which are caught accidentally in shrimp trawls and discarded at sea. These amounts are all relatively small, however.

Since the tuna-bait fishery has declined in importance the anchoveta is exploited hardly at all except in the Gulf of Panama and Magdalena Bay. Such areas as Guaymas Bay, Ahome Point, and the Gulf of Guayaquil could probably support substantial fisheries. In the Gulf of Panama the catches from Isla Verde and Panama Viejo exceed those of the very large area to the southeast of Panama Viejo. Since the exchange of fish among areas within the Gulf of Panama is limited, the catch could almost certainly be substantially increased by heavier fishing to the southeast of Panama Viejo. It is conceivable that this could reduce the recruitment in subsequent years, however.

TABLE XIII

Estimated catches of anchovetas in metric tons by the tuna-bait fleet. The 1946–1954 data are from Alverson and Shimada (1957), while those for 1955–1966 are from unpublished data of the Inter-American Tropical Tuna Commission

	Santa Maria Bay, Magdalena Bay, and Almejas Bay	Kino Point	Guaymas Bay	Ahome Point	Banderas Bay	Gulf of Tehuantepec	Gulf of Fonseca	Gulf of Nicoya
1946	107	0	668	173	0	0	145	327
1947	369	0	1181	541	0	0	131	209
1948	797	0	0	1203	0	0	4	26
1949	904	0	3	1009	5	0	12	4
1950	1816	31	1747	297	1441	0	68	0
1951	904	0	1572	1521	11	3	624	0
1952	1358	0	2122	263	255	3	1038	0
1953	1259	0	1290	601	89	0	20	0
1954	416	0	1596	414	1193	5	173	0
1955	1106	0	818	575	290	0	239	0
1956	1024	0	1354	581	764	4	8	0
1957	2177	0	776	1756	0	55	0	0
1958	3119	0	24	<0.5	0	0	0	0
1959	1066	0	0	138	0	0	0	0
1960	455	0	0	0	32	0	0	0
1961	87	0	0	7	0	0	0	0
1962	5	0	0	70	6	0	0	0
1963	145	0	0	4	21	0	0	0
1964	18	0	0	0	68	0	0	0
1965	106	0	0	2	0	0	0	0
1966	65	0	0	11	0	0	0	0

TABLE XIII (continued)

	Montijo Bay	Gulf of Panama	Colombia	Northern Ecuador	Gulf of Guayaquil	Peru	Other
1946	0	22	0	0	0	0	0
1947	76	521	0	0	0	0	7
1948	8	1435	29	0	0	0	0
1949	71	1865	42	0	0	0	0
1950	29	665	65	7	0	0	2
1951	9	742	160	1	653	0	0
1952	16	3359	192	0	620	0	0
1953	11	2262	336	0	3	0	0
1954	0	2760	45	0	0	3	0
1955	15	1474	273	0	0	0	3
1956	0	1995	27	1	6	0	282
1957	7	2600	10	0	9	0	122
1958	0	1447	1	3	634	256	14
1959	23	777	5	0	232	56	0
1960	24	778	2	0	189	16	2
1961	0	505	9	0	144	16	0
1962	0	257	0	0	46	0	62
1963	0	0	0	0	0	0	32
1964	0	0	0	0	0	0	48
1965	0	7	0	0	0	0	8
1966	0	179	<0.5	0	1	0	0

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

6.11 Limitation or reduction of the total catch

For regulation of the purse-seine fishery the Pacific waters of Panama have been divided into the following zones: 1, Chiriqui province; 2, Montijo Bay; 3, Bahia Parita; 4, Punta Chame to Isla Chepillo; 5, Isla Chepillo to Bahia San Miguel, including the Las Perlas Islands. There are only two plants for reduction of fish to meal and oil in Panama, both located in Zone 4. No additional plants may be constructed in that zone, and the two existing plants are limited to a total of 32 fishing vessels. If it is desired to establish a plant in another zone the prospective management must demonstrate to the government's satisfaction, by exploratory fishing, that the supply of fish is adequate for that purpose.

6.12 Protection of portions of the population

Fishing by purse-seine vessels is prohibited in the Gulf of Panama between the entrance of the Panama Canal and the mouth of Rio Tapia (3 km east of Rio Juan Diaz) and in two areas southwest of Punta Chame. This regulation is not enforced, however.

The regulations for the catching of anchovetas by foreign vessels for bait in the territorial waters of Panama have been changed frequently. The regulations have usually provided for a closed season beginning in October, November, December, or January and ending in January, February, March, or April. Parts of the northern portion of the Gulf of Panama have been closed to bait fishing. The most recent regulation (Anon., 1959) permits fishing during the entire year, but the area between the entrance of the Panama Canal and Punta Chame is closed to fishing by foreign vessels.

Foreign vessels were not permitted to fish for anchovetas or other species for bait in the Ecuadorian portion of the Gulf of Guayaquil from 1952 to 1957.

6.2 Control or alteration of physical features of the environment

The possible effect of the jetty near the entrance of the Panama Canal on the migration of the anchoveta has been mentioned in Section 3.51.

6.3 and 6.4 Control or alteration of chemical and/or biological features of the environment

It has been proposed that a sea-level canal connecting the Atlantic and Pacific Oceans be built in Panama with atomic explosives. Investigations are being conducted to determine if the use of such explosives would adversely affect any of the aquatic organisms, including the anchoveta.

6.5 Artificial stocking

6.52 Transplantation; introduction

Prior to 1948 there existed a substantial fishery for anchovetas for bait in the Gulf of Nicoya. The population is reported to have declined abruptly in 1947, coincident with a heavy bloom of red tide, presumably Gymnodinium sp. (Peterson, 1956). The catches were greatly reduced in 1948 and 1949, and no anchovetas were caught there for bait thereafter (Table XIII). Extensive collections of fish were made in the Gulf of Nicoya for more than a year in 1952 and 1953, but no anchovetas were found.

In October 1953 about 500,000 anchovetas caught in Bahia San Miguel in the Gulf of Panama were transported aboard a tuna clipper to the Gulf of Nicoya and released there in the vicinity of Chira Island (Schaefer, 1954). Since then anchovetas have been caught frequently in the Gulf of Nicoya, but only in amounts so small as to be of negligible commercial value.

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SYNOPSIS OF FISHERIES BIOLOGICAL DATA

This is one of a series of documents issued by FAO, CSIRO and USFWS concerning species and stocks of aquatic organisms of present or potential economic interest. The primary purpose of the series is to make existing information readily available to fishery scientists according to a standard pattern, and by so doing also to draw attention to gaps in knowledge. It is hoped that synopses in the series will be useful to other scientists initiating investigations of the species concerned or of related ones, as a means of exchange of knowledge among those already working on the species, and as the basis for comparative study of fisheries resources. They will be brought up to date from time to time as further information becomes available either as revisions of the entire document or their specific chapters.

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